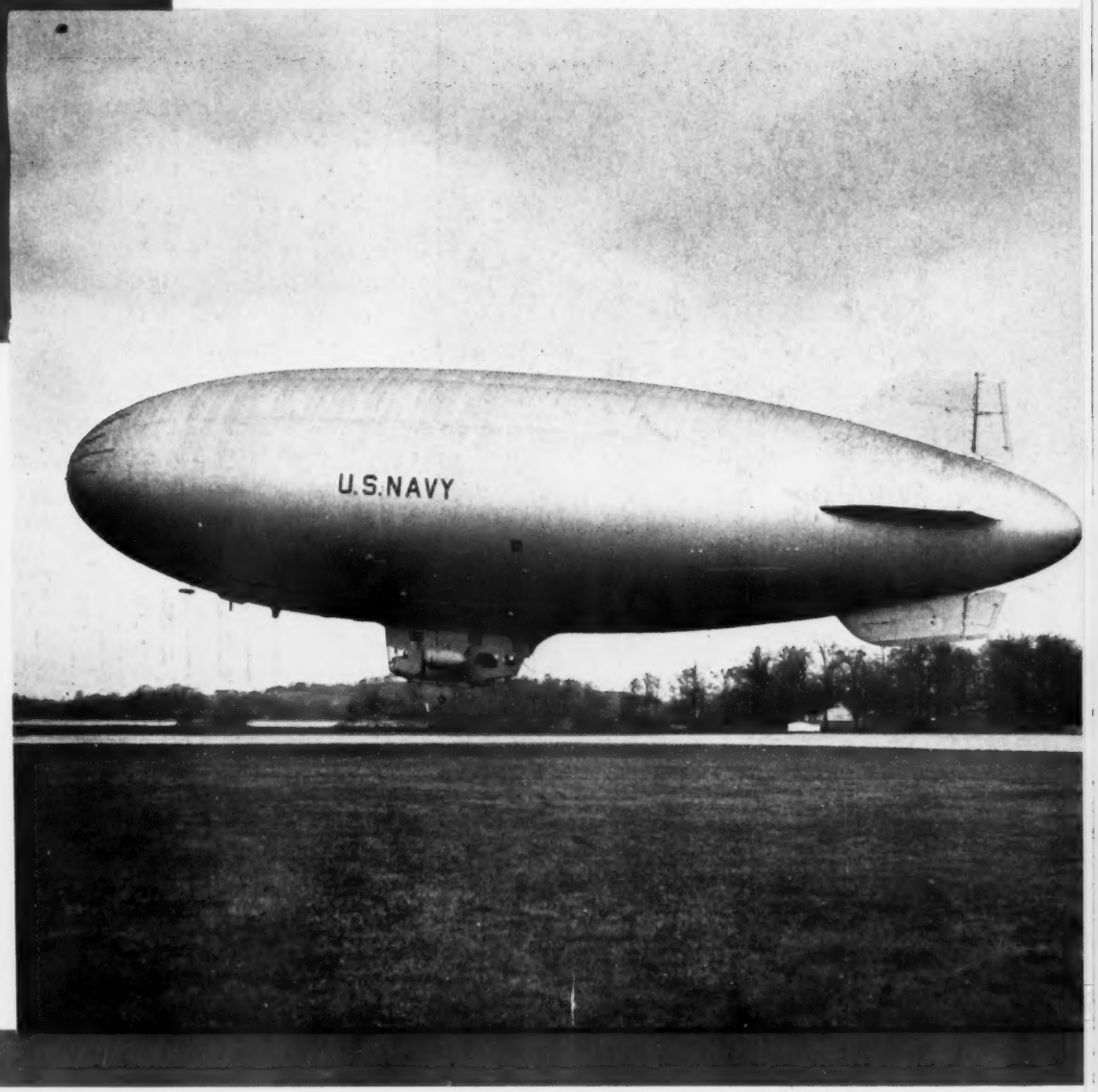
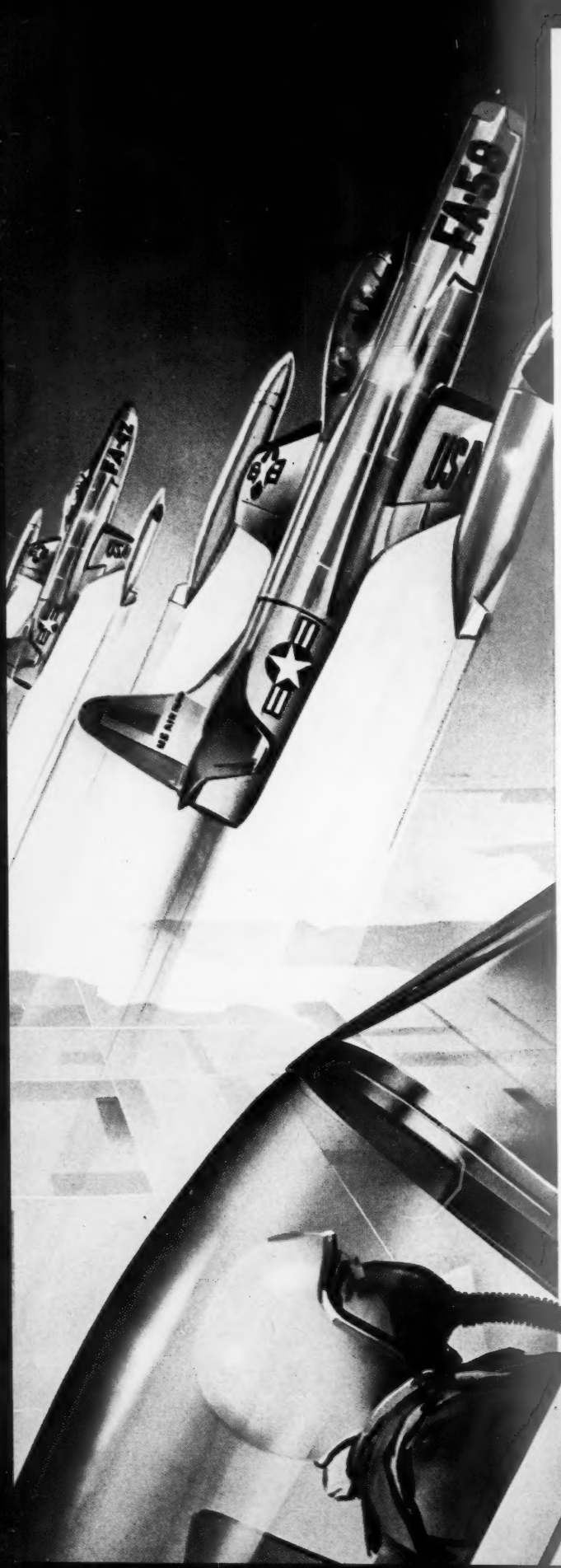
Aeronautical Engineering REVIEW



MARCH, 1954



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LEADER IN THE DESIGN, DEVELOPMENT AND MANUFACTURE OF AVIATION FUEL METERING DEVICES

A—18

Aeronautical Engineering REVIEW

Vol. 13 — No. 3 MARCH, 1954

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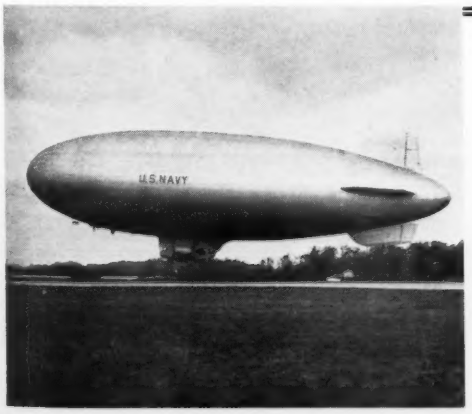

Cover—The first of the ZP4K class of airships, being built for the U.S. Navy by Goodyear Aircraft Corporation, is shown at Wingfoot Lake Field, Akron, Ohio. The ZP4K incorporates the Navy's latest devices for locating and attacking enemy submarines. The gas capacity of the airship's neoprene-coated cotton envelope is 527,000 cu.ft. of helium. A crew of eight men and officers will man each craft. The total number of ZP4K class ships on order was not announced.

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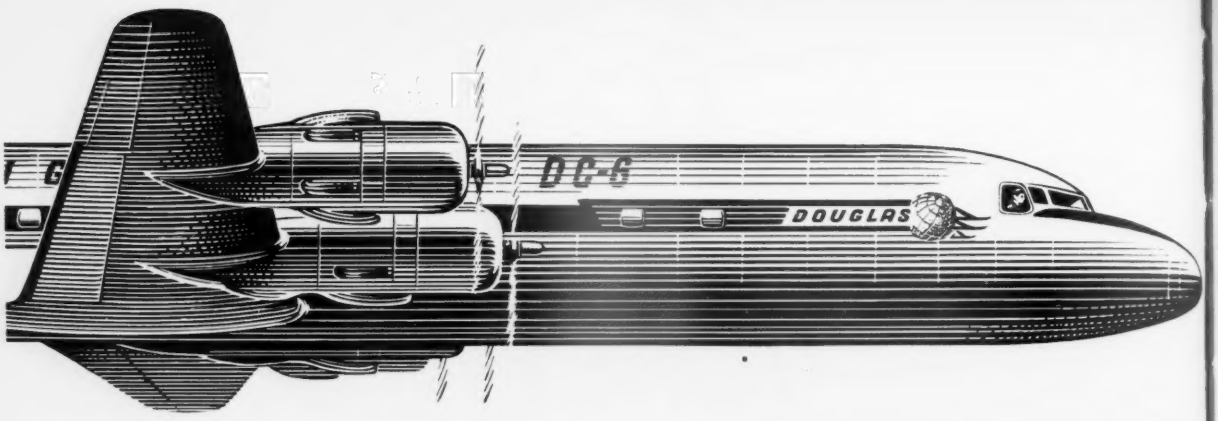

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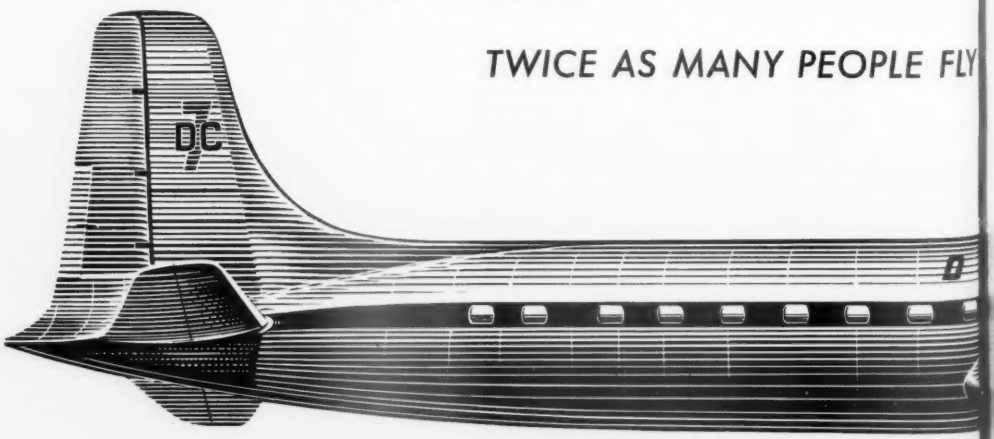
JAL *Japanese* • KLM *Netherlands* • LAI *Italian* • *LAN *Chilean* • NATIONAL *U. S.* • *NORTH AMERICAN *U. S.* • NORTHWEST *U. S.* • PAL *Philippine*
PANAGRA *U. S.* • PAN AMERICAN *U. S.* • SABENA *Belgian* • SAS *Danish Norwegian Swedish* • SLICK *U. S.* • SWISSAIR *Swiss*
TAI *French* • UAT *French* • UNITED *U. S.* • WESTERN *U. S.* *Soon



TWICE AS MANY PEOPLE FLY

I.A.S. News Notes

March 1954

SECOND EDITION OF VOCATIONAL GUIDANCE MANUAL

The 1954 edition of "A Guide to the Engineering Professions in the Aviation Industries," is now ready for distribution. Revisions, taking into account changes in the aeronautical picture since the original publication in 1953, have been made. Several sections of the booklet have also been expanded, and corrections and adjustments in the text were made where necessary, particularly with regard to salary ranges for engineering personnel.

As before, the manual will be made available to educational centers, vocational counselors, IAS members, IAS Sections, and Student Branches, and others interested in directing qualified students toward a career in aeronautical engineering.

Individual requests for the booklet will be filled free of charge. For bulk orders running into high numbers, a charge of $0.15 per copy will be made.

Requests for the publication should be directed to the New York office of the IAS.

* * * * * * * * * * *

WEST COAST FOURTH ANNUAL STUDENT CONFERENCE

May 6, 7, and 8 have been set as the dates for the West Coast Student Conference which will be held in Los Angeles. Plans for the three-day program are not being finalized by the Student Activities Committee and will be announced shortly.

* * * * * * * * * * *

NECROLOGY

Noel Warner (Jeff) Bouley, MIAS, Assistant Chief Engineer, San Diego Division, Consolidated Vultee Aircraft Corporation, January 24.

Lt. Richard L. Morgan, USAF, TMIAS, on January 7.

Volney C. Finch, MIAS, Professor of Mechanical Engineering, Stanford University, on November 9.

* * * * * * * * * * *

NATIONAL MEETINGS CALENDAR

March 12	Flight Propulsion Meeting, Hotel Carter, Cleveland. (Closed)
June 21-24	Annual Summer Meeting, IAS Building, 7660 Beverly Blvd., Los Angeles, California.
Aug. 9-11	Turbine Powered Air Transportation Meeting, Seattle, Wash.

* * * * * * * * * * *

CALENDAR OF SECTION MEETINGS

Mar. 3--Philadelphia Section: Engineers Club of Philadelphia. Dinner, 7:00 p.m.; Meeting, 8:00 p.m. "The Thermal Barrier" by Dr. Nicholas J. Hoff, Head, Department of Aeronautical Engineering, Polytechnic Institute of Brooklyn.

Mar. 10--Niagara Frontier Section (formerly Buffalo Section): Tonnewanta Veteran's Club (Braunschidel American Legion Post), 3354 Delaware Ave., Kenmore, N.Y. Meeting, 8:00 p.m. "Comet--Special Design and Development Features" by Robert L. McIntyre, of The de Havilland Aircraft of Canada, Ltd. Lecture to be illustrated with film.

Mar. 11--Los Angeles Section: IAS Building. Specialist Meeting, 7:30 p.m. "A Review of Slender Body Theory--Wings, Bodies, and Wing-Body Combinations" by Dr. Mac C. Adams, Aerodynamics Group, Santa Monica Division, Douglas Aircraft Company, Inc.

Mar. 18--Los Angeles Section: IAS Building. Confidential, Social hour, 6:00 p.m.; Dinner, 7:00 p.m.; and Meeting, 8:15 p.m. "The MIG-15" by Major Gen. Albert O. Boyd, USAF, Commanding General, WADC.

Mar. 23--Los Angeles Section: IAS Building. Specialist Meeting, 7:30 p.m. "Plastics in the Aircraft Industry" by Dr. W. E. Braham, of Zenith Plastics Company.

Mar. 24--Chicago Section: Museum of Science and Industry. Dinner, 6:30 p.m.; Meeting, 7:30 p.m. Symposium on the development of design and performance of aircraft. Names of participating speakers not known at press time. This is the Annual Student Meeting, arranged by Student Members.

Mar. 24--Hagerstown Section: Packet Room, Terrace Restaurant. Meeting, 8:00 p.m. Thomas J. Harris, Manager, Cargo Sales, American Airlines, Inc., to speak on commercial air-cargo potentialities.

Mar. 24--St. Louis Section: Engineers Club, Meeting, 8:00 p.m. "Supersonic Aerodynamics" and "The Thermal Barrier" to be discussed. Names of speakers not known at press time.

Apr. 6--Boston Section: Faculty Club, Massachusetts Institute of Technology. Dinner, 6:30 p.m.; Meeting, 8:15 p.m. "Development of High-Speed Water-Based Aircraft" by Ernest G. Stout, Staff Engineer, Consolidated Vultee Aircraft Corporation. Lecture to be illustrated with slides and film.

Apr. 8--Los Angeles Section: IAS Building. Specialist Meeting, 7:30 p.m. "Miniaturization of Electronic Circuits and Components as used in Aircraft" by Dr. Samuel G. Lutz, of Hughes Aircraft Company.

* * * * * * * *

IAS News

A Record of People and Events of Interest to Institute Members

Annual Business Meeting of the Institute

Reports of President, Treasurer, and Director

THE TWENTY-SECOND ANNUAL MEETING of the members of the Institute was held at the Hotel Astor, New York, on January 27, 1954. The President, Charles J. McCarthy, presided.

Ernest G. Stout, Teller, reported that he had received and counted 1,152 valid proxies for voting at the Annual Meeting—a quorum of the voting membership. L. B. Richardson, Chairman of the Nominating Committee, placed in nomination the following members for election to vacancies on the Council: J. L. Atwood, W. A. M. Burden, V. E. Carbonara, J. W. Larson, C. J. McCarthy, E. T. Price, Elmer A. Sperry, Jr., and E. S. Thompson, for a term of 1 year each; P. R. Bassett, M. G. Beard, J. A. Herlihy, E. M. Powers, and R. C. Sebold, for a term of 3 years each; and the following area councilors for a term of 1 year each: Eastern Area—G. W. Baughman and William M. Duke; Central Area—Ralph N. DuBois and H. F. Waring; Western Area—J. E. Barfoot and W. T. Immenschuh. On motion duly made, seconded, and carried, they were unanimously elected. The following were nominated and elected in like manner to serve on the Nominating Committee for 1954: T. P. Wright, Chairman; Walter S. Diehl; H. L. Dryden; Sherman M. Fairchild; C. C. Furnas; Hall L. Hibbard; J. C. Hunsaker; and Clark B. Millikan.

The Annual Reports of the President, Treasurer, and Director were read and approved. (See the following pages for the complete reports.)

The Secretary presented a list of honors conferred by the Institute in 1953 as follows:

The Thurman H. Bane Award to Benjamin F. Greene, Jr., Air Force Cambridge Research Center; The Octave Chanute Award to William B. Bridgeman, Engineering Test Pilot, Douglas Aircraft Company, Inc.; The John Jeffries Award to Capt. Charles F. Gell USN (MC), Aviation Medicine Acceleration Laboratory, NADC, Johnsville, Pa.; The Robert M. Losey Award to Henry T. Harrison, Jr., Chief Meteorologist, United Air Lines, Inc.; The Sylvanus Albert Reed Award to Ernest G. Stout, Staff Engineer in Charge of Hydrodynamic Research and Development, San Diego Division, Consolidated Vultee Aircraft Corporation; The Lawrence Sperry Award to Donald Coles, Research Fellow, Jet Propulsion Laboratory, California Institute of Technology; and the Wright Brothers Lecturer, Glenn L. Martin, who spoke on "The First Half-Century of Flight in America."

Honorary Fellowships in the Institute to: American—Preston R. Bassett, President, Sperry Gyroscope Company Division, The Sperry Corporation; Foreign—Sir William Farren, Technical Director, A. V. Roe & Company, Ltd., England.

Fellowships in the Institute to: Myron G. Beard, Chief Engineer, American Airlines, Inc.; L. P. Coombes, Chief of Aerodynamics, Aeronautical Research Laboratories, Australia; Fred N. Dickerman, Chief Engineer, Chance Vought Aircraft, Inc.; Edward M. Powers, Vice-President, Engineering, Curtiss-Wright Corporation; Perry W. Pratt, Chief Engineer, Pratt & Whitney Aircraft Division, United Aircraft Corporation; Norbert E. Rowe, Technical Director, Blackburn & General Aircraft Ltd., England; Maurice Roy, Director of The Office National d'Etudes et de Recherches Aeronautiques (O.N.E.R.A.), France; E. E. Sechler, Professor of Aerodynamics, California Institute of Technology; E. C. Wells, Vice-President—Engineering, Boeing Airplane Company; Carlos Wood, Chief Preliminary Design Engineer, Santa Monica Plant, Douglas Aircraft Company, Inc.

The Secretary announced that the Council had elected the following officers of the Institute for 1954: President, J. L. Atwood; Vice-Presidents, W. A. M. Burden, J. W. Larson, E. T. Price, and E. S. Thompson; Director, S. Paul Johnston; Treasurer, Elmer A. Sperry, Jr.; Secretary, Robert R. Dexter; and Controller, Joseph J. Maitan.

ROBERT R. DEXTER
Secretary

President's Report—1953

AN EXAMINATION OF THE Annual Reports of the Treasurer and the Director which follow will show that the Institute has had another successful and active year. Again our income has exceeded our outgo, and we have been able to lay aside a few dollars to help us through any "lean" periods that may lie ahead. Several years ago the Council adopted a policy of setting up special reserve funds for specific purposes out of any surpluses that may develop from year to year. This practice has been continued, and, as a result, we now have available for future use certain funds to help take care of building maintenance, modernization of equipment, support of future special events (such as our International Conferences), and, most important, provision for our employees retirement fund.

Consistent with our basic mission, Institute meetings, publications, and other activities continue to be a primary source of unclassified technical information for our industry. In spite of security restrictions, our meetings at all levels (national, regional, and local) have been maintained at a high standard of quality. A good indication is the widespread quotation by the general aeronautical press of IAS papers and publications.

Reports from our Western Region indicate a very satisfactory level of activity throughout. Student conferences were held during 1954 in four regions of the United States.

Gratifying progress has been made toward a solution of the economic problems at our two facilities in Los Angeles and San Diego. Intensive promotion of the usage of the Los Angeles building during the year has brought it close to the "break-even" point, and it is estimated that it should show black figures for 1954. Substantial progress has been made in the reactivation of the San Diego facility. There is every reason to look forward to a considerable reduction in its operating deficit during the coming year.

A number of special events marked the passage of 1953. Among them, the Institute played an active part in the commemoration of the Fiftieth Anniversary of Powered Flight. Outstanding was the construction and dedication (at the Annual Summer Meeting Dinner in Los Angeles) of an accurate full-scale reproduction of the Kitty Hawk "Flyer" of 1903. The project was conceived and activated by E. W. Robischon, IAS Western Region Manager, and was carried to completion under the direction of A. L. Cleveland, of Lockheed. Twenty-five companies in the industry contributed material, parts, and labor. The machine is now on permanent display in our Los Angeles building.

During the entire year our libraries, both East and West, were kept constantly busy supplying historical material on the Wright brothers to writers, researchers, advertising copy writers, and Corporate Members.

Our part in the Anniversary celebration culminated in the reading of the Seventeenth Wright Brothers Lecture by Past-President Glenn L. Martin in Washington on December 17.

The year was marked also by the Fourth International Aeronautical Conference with The Royal Aeronautical Society of Great Britain in London in September. IAS members are familiar with the results, since the event was well covered in both RAeS and IAS publications. Suffice to say here that the benefits of such periodic meetings have been recognized on both sides of the Atlantic, and plans are now going forward for the Fifth Conference to be held in Los Angeles in June, 1955.

Early in 1953 the first edition of the Institute's Vocational Guidance Manual, "A Guide to the Engineering Professions in the Aviation Industries," was published. This project had been initiated by Wellwood Beall, IAS President for 1952. Over 32,000 copies were printed, but the demand was such that the supply was exhausted by midsummer. Because of the obvious need for such a manual, the Council authorized a revision and reprinting, which is now being distributed.

Not long ago a report was presented to the Council which brought out a few interesting facts about the growth of the Institute during the past decade. The list is too long for reproduction here, but from the overall point of view these may be of interest. In the period 1943 to 1953 our graded membership increased almost exactly 100 per cent, and our student enrollment over 160 per cent. Organized Sections grew from 10 to 26 (up to 160 per cent), and Student Branches went from 49 to 69 (68 per cent). Annual income is not a good index because it varies with the health of industry, but it is of interest to note that last year's was about twice that of 1943. Operating reserve is more significant. In the 10-year period, not including specially earmarked funds that have been received as gifts, etc., our reserves stand at 675 per cent of what they were 10 years ago. And in spite of the increased tempo of activity that such figures connote, the operating staff of the Institute has increased only 16 per cent.

From these brief comparisons the conclusion may be safely drawn that this organization is carrying out its proper role in serving the technical needs of the aviation industry.

I wish to express my sincere thanks to the Officers and Council of the Institute for their wise counsel and loyal support and for the sustained and active part they have taken in the affairs of the society.

My thanks go also to members all over the country who have presented technical papers or contributed in other ways to the activities of the society.

I should like also to express my personal thanks to the IAS staff which provides for a continuity of our effort over the years.

It is the cumulative effect of the labors of so many that makes the Institute such a vital force for the advancement of the aeronautical sciences.

CHARLES J. MCCARTHY
President, 1953

Treasurer's Report—1953

THE MOST ACTIVE FISCAL YEAR in the Institute's history ended September 30, 1953. The gross income was $595,129.86 and the net income after reserves was $4,045.80.

The overall increase in income was 15.2 per cent over the preceding year. Expenses (including authorized Reserves) increased 15.9 per cent. The cost of meetings, general, annual, and international, increased 38.1 per cent, which is reflected by better services to the membership of the society. It is through such interchange of ideas and by increased contact with Section officers and their committees that the IAS is better able to serve the needs of the aeronautical industry.

The conservative policies maintained by the Council are reflected by a steady financial growth. The President's and Director's reports show some interesting facts concerning the growth of the society in the last 10 years. A further indication is shown by the following comparisons.

Advertising revenue was 55 per cent higher in 1953 than it was in 1943. This increased income was partly plowed back in the form of more editorial pages, an 18 per cent increase on an average issue (79 to 93 pages). A further application of the theory of plowing back earnings into services is shown in the average monthly pages published in the JOURNAL OF THE AERONAUTICAL SCIENCES. In 1943 the 12-month average was 41 pages—in 1953 it was 72 pages, an increase in text material of 76 per cent. The Catalog has been accepted by the industry as one of its most important buyers' guides. During the past 9 years it grossed over $300,000.

The IAS gross income, including the first edition of the Catalog, as of September 30 during this 10-year period increased 97 per cent and expenses increased 105 per cent. The reserves and net unexpended income have increased significantly. These funds have been accumulated to provide the membership with continued services during a less favorable economic environment. It is notable that with all activity at least doubled, the personnel at headquarters increased from 43 to 50 or only 16 per cent.

Among new and improved IAS activities since 1943 are the issuance of

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

Statement for the Fiscal Year October 1, 1952, to September 30, 1953

Consolidated Balance Sheet and Operating Statement

ASSETS				LIABILITIES, RESERVES, AND UNEXPENDED INCOME		
Unrestricted				*Unrestricted Funds:*		
General Fund:				Accounts Payable and Deposits	$ 69,362.92	
Cash on Deposit	$ 89,834.24			Deferred Credits to Income (Dues and Subscriptions)	108,305.75	
Accounts Receivable—Net	29,408.00			Deferred Income—San Diego Building	23,189.77	
Advance on Intrafund Accounts	43,840.32			Contingency Reserves	167,000.00	
Deposits and Prepayments	11,255.26			*Surplus:*		
Furniture and Fixtures	5,000.00			Balance September 30, 1953	551,986.29	
Investments	740,504.91					
Books, Prints, Models, Medals, etc.	1.00					
Aeronautical Index	1.00					
Total Unrestricted Assets			$919,844.73	**Total**		$919,844.73
Restricted						
Special:						
The Minta Martin Aeronautical Fund	$599,011.00					
Others:						
The Thurman H. Bane Award Fund	$ 130.81					
The Sherman M. Fairchild Fund	13,600.29					
The Paul Kollsman Fund	69,000.00					
The Vernon Lynch Award Fund	38,444.11					
The Sylvanus Albert Reed Award Fund	13,531.90					
The Lawrence Sperry Award Fund	13,440.00					
New York Building Contingency Fund	104,525.24					
Los Angeles Building Operating Fund	23,697.72					
Pacific Aeronautical Library Fund	17,526.02					
San Diego Building Capital and Library Fund	3,525.36					
San Diego Building Operating Fund	5,917.85					
The G. M. Giannini Fund	5,000.00	$308,339.30				
Total Restricted Assets			$907,350.30	*Restricted Funds*		$907,350.30
Facilities						
Buildings, Land and Equipment:						
New York		$220,415.26				
Los Angeles		398,741.79				
San Diego (land leasehold)		176,706.11				
Total Facilities			$795,863.16	*Land, Buildings, and Equipment*		$795,863.16

Statement of Income & Expenses

Income:		
Advertising Revenue	$283,145.00	
Dues and Entrance Fees	223,287.27	
Subscriptions	65,803.46	
Income from Investments	21,373.15	
Miscellaneous	1,520.98	
Total Income		$595,129.86
Expenses:		
Publications	$236,433.51	
Salaries (Administrative, Accounting, and Clerical)	123,488.80	
Employees' Retirement Fund, Reserves, Social Security, etc.	44,373.32	
Travel, Meetings and Reserve Therefore	38,412.70	
Libraries (excluding P.A.L.)	23,883.93	
Building Maintenance and Reserve for Alterations and Repairs	18,750.58	
Printing, Postage, Telephone, and Telegraph	13,635.48	
Furniture, Fixtures, and Reserve Therefore	10,416.85	
Office Supplies and Expenses, Insurance	10,071.95	
West Coast Offices	8,783.17	
Miscellaneous	2,833.77	
Total Expense		$591,084.06
Net Unexpended Income		$ 4,045.80

the VOCATIONAL GUIDANCE MANUAL, an annual ROSTER OF MEMBERS, the semimonthly News Letter to Student Branch officers and a periodic News Letter to Section officers, an automatic distribution of technical films from our library, Student Branch and Membership promotion literature, a Student Branch officers kit of information and procedures, the printing of meeting notices for Sections, and an increase in the number of regional Student meetings. Such services account in part for the increase in costs and require considerable staff time and effort.

In October, 1952, the employees became eligible to participate under the Federal Insurance Contributions Act. This, together with the Retirement Pension Plan, provides employees with satisfactory security benefits after age 65. The plan has resulted in a reduced rate of turnover in supervisory and administrative personnel.

The Finance Committee, acting with the Investment Service Department of the Chase National Bank, has maintained careful control of the Institute's investments. The general investment funds of the IAS have a market value in excess of our cost values.

The Council has reviewed and approved the budget for the year 1953–1954.

The Los Angeles Building incurred a deficit this year of $1,600 against $21,600 in receipts. Budget forecasts show a slight profit for 1954. The PAL ended the year with a net operating income of $6,524.94.

The San Diego Building operation cost $5,043.28 for a 9-month period. This is a result of reactivating the building with immediate straight-line costs and no initial income. On the basis of current income it is estimated that there is a possibility that the San Diego building might break even during 1954.

Harris, Kerr, Forter & Company, Certified Public Accountants, have examined the books and records in New York, Los Angeles, and San Diego. They report that the Balance Sheet and related statements of Income and Expenses fairly present the financial position of the Institute as of September 30, 1953. A digest of their report is published in this issue.

Any additional details are available to members at the national office.

PRESTON R. BASSETT
Treasurer

Director's Report—1953

AS CAN BE SEEN in detail from the reports of the President and the Treasurer, the Institute has had an extremely active year and has once again ended its fiscal period in the black. The continuing success of this activity can be credited to the interest and attention given to Institute affairs by our Council and elected officers and to the loyalty and hard work of our staff people both in New York and on the West Coast. The entire organization labors as a cohesive unit in furthering the interests of our membership and in fostering the aims and objectives of the society.

Meetings

Institute meetings at all levels (national, regional, local, and student) attained the highest averages yet recorded for attendance and for quality of presentation. In spite of the difficulties imposed by problems of security, our Secretary and our program committees have maintained a high standard of quality in the papers that have been selected for our meetings and for publication in the JOURNAL and the REVIEW. The problem is not simple when it is realized that during the calender year IAS Sections held 237 regular meetings and our Student Branches 319. Each of these meetings required *at least* one prepared paper. Counting in the requirements of the Twenty-First Annual Meeting in January, the Seventh Annual Propulsion Meeting in Cleveland in March, the Annual Summer Meeting in Los Angeles in July, and the Fourth International Aeronautical Conference in London in September, something close to 650 technical papers were selected, prepared, and presented under Institute auspices. In addition, the Historical Associates conducted a number of meetings at which papers of an historical nature were read.

One of the most important events of the year was the Fourth International meeting referred to above and in the President's Report. Discussions are under way by the councils of both societies leading toward the organization of the Fifth International Aeronautical Conference in Los Angeles in June, 1955.

Membership Services

The policy of strengthening all Section activities was continued. An attempt has been made to visit all Sections (by an officer from the National Office) at least once during the course of the year. A Section Chairman's News Letter has been instituted, as well as a periodic news letter for Student Branch Chairmen. By these means an attempt is being made to circulate ideas and information among Sections and Branches and to keep them all posted on IAS policies and programs. At the Annual Meeting in January (1954) a conference was called of all Section Chairmen (or their representatives) to discuss common problems and to determine how best the National Organization can help the work in the field.

One of the aids offered to Sections and Branches is an expanded film library service. Gabriel Giannini recently made a gift to the Institute of $5,000 for this purpose. The money will be used to make more and better technical films available to Student Branches in particular.

Membership

Our membership continues to grow at a steady and a satisfactory rate (see Table 1). No national membership drives or solicitations have been undertaken. The best source of new membership is through active Sections and intelligent Section activity. At the end of the year our 26 Sections had an active enrollment of 8,408, approximately 87 per cent of our total. This is the highest figure in our history—and a healthful indication.

Total membership stands at the highest recorded figure. We now have 9,718 regularly graded members, plus 2,672 students, for a total of over 12,000. The breakdown of membership by grades for the past 3 years is shown in Table 1.

Publications

Editorially, the JOURNAL continued to occupy the top position among aeronautical scientific publications. Its content was maintained at 72 pages per issue (or above) throughout the year. The REVIEW strengthened its editorial position at the end of the year by the appointment of editorial committees in all fields of its engineering coverage to assist its editorial staff in the selection of material of major interest to its readers.

All Institute publications showed gains both in circulation and in earnings during the past year. As will be shown from the Treasurer's Report, the REVIEW accounted for a large share of the Institute's surplus for the year. The December issue (which commemorated the fiftieth Anniversary of Powered Flight) contained the second highest total of advertising pages in the REVIEW's history but grossed more in dollars than any other prior issue. Its 122 advertising pages brought in over

TABLE 1
Membership Breakdown—Comparisons by Calendar Year

	12/31/51	12/31/52	12/31/53
Temporary Honorary Members	14	18	15
Honorary Fellows	24	26	28
Fellows	183	191	197
Associate Fellows	665	699	757
MEMBERS	3,218	3,511	3,878
Associate Members	368	399	440
Historical Associate Members	67	70	74
Technical Members	4,102	4,238	4,329
Total Graded	8,641	9,152	9,718
Student Members	3,006	2,796	2,672
Totals	11,647	11,948	12,390

$36,000 in revenue. The gross revenue of the REVIEW for the calendar year stood at $255,000 or about 24 per cent ahead of 1952.

The AERONAUTICAL ENGINEERING CATALOG also showed a substantial gain. Its gross billings of $47,000 were about 8 per cent ahead of last year.

The Sherman M. Fairchild Publication Fund continued to play an important part in the Institute's publishing program during the year. It added to its prior list 37 new papers and distributed over 9,000 copies of all papers.

To help commemorate the Fiftieth Anniversary of Powered Flight, the *Chronicle of the Aviation Industry in America*, compiled by Welman A. Shrader, our Director of Publications, and published by the Eaton Manufacturing Company, was distributed free of charge to all IAS members. Also, over 32,000 copies of the First Edition of the Institute's VOCATIONAL GUIDANCE MANUAL, "A Guide to the Engineering Professions in the Aviation Industries," were printed and distributed. A second edition, including some revisions to bring the material up to date, was prepared by the end of the year and will be distributed (also over 30,000) early in 1954.

Libraries

Institute libraries on both East and West coasts continued to serve the needs of our membership, both Corporate and individual. The Pacific Aeronautical Library, under the direction of Mrs. Nell Steinmetz, has been increasingly active in its function of supplying the technical libraries of the West coast aviation industry with the day-to-day information they need to carry on their essential defense effort. This important activity is self-supporting, being paid for by direct subscription by the users. Both main libraries carried a heavy load during the year because of the demands by members and company representatives for material of an historical nature concerning the Wright brothers. The Institute's collections of Wright memorabilia were used extensively during the year.

With the return of the IAS Building in San Diego to IAS activities, plans are afoot to build up the library at that facility in order better to serve the industry in the vicinity.

Facilities

The policy of modernizing all IAS facilities during this period of relative prosperity has been continued. Not only have reserves for the future been set up, but worn out or inefficient equipment is being retired and replaced. For example, fully up-to-date projection equipment, both for slides and for films, was made available both in New York and Los Angeles. Also, the Los Angeles kitchen equipment, which was found to be inadequate for present loads, has been redesigned and is being partially replaced. Improvements were made in the San Diego building when reactivated which will make it more effective for our purposes.

Historical Activities

As mentioned above, the celebration of the Fiftieth Anniversary of Powered Flight caused considerable activity among our Historical Associates. The construction and dedication of the Wright Reproduction by the Los Angeles Section was in itself a notable achievement.

Our librarians and our Custodian of Archives put in many additional hours of research during the year. Several notable programs on the early days of the Wrights were put on by the Historical Associates, both East and West.

Following the example set by the Western group, an Eastern section was organized and a number of meetings were held in the New York headquarters.

The editorship of AERONAUTICA was transferred to the Western Region at the first of the year.

General

The Western Region Manager, E. W. Robischon, was on leave of absence to AGARD for 4 months early in the year. During this period the activities in the region were supervised by frequent staff visitations from the National Office.

I should like to take this opportunity to express to the staff of the Institute my thanks and appreciation for the loyal support they have continued to give me in carrying out the work of this organization.

S. PAUL JOHNSTON
Director

General IAS News

Longren Aircraft Joins IAS

The Longren Aircraft Company, of 2576 W. Carson St., Torrance, Calif., has become a Corporate Member of the Institute of the Aeronautical Sciences. The company, a prime contractor and subcontractor in the aircraft industry, was founded in Kansas City in 1930 and was moved to California in 1939.

Longren has devoted its entire energy to the developing of new forming methods for light metals. It is a pioneer in developing new structural and metal-forming theories to the point where they have become accepted as standard industry-wide production procedures.

As early as 1932, Longren created a full-monocoque stretch-formed fuselage—from 17 ST aluminum—the first of its kind in the country. The company took out various patents on this type of structure, and after this nation's entry into World War II, it made all of its patent rights available to the entire aircraft industry at no cost. Among the processes covered by these patents are (1) a method of gripping aluminum sheet with curved grippers which makes it possible to form certain needed shapes not producible by other means and (2) a system of assembling sheet-metal parts which permits internal and external components to be prepunched, thus eliminating drilling on assembly.

1954 AEDC Industry and Educational Advisory Board

The membership of the 1954 Industry and Educational Advisory Board of the Arnold Engineering Development Center, Tullahoma, Tenn., was recently announced. The purpose of this Board is to review and to submit recommendations on all policy matters pertaining to the design and construction of the AEDC, operation of the Center, and requirements and plans for additional technical facilities. The Board's membership is appointed annually by the USAF Chief of Staff and is composed of some of the leading individuals in the aircraft industry, education, and engineering.

The members of the Board are: Edward C. Wells, FIAS, Vice-President—Engineering, Boeing Airplane Company; Neil Burgess, MIAS, Manager, Development Operations, Aircraft Gas Turbine Division, General Electric Company; Ronald M. Hazen, FIAS, Director of Engineering, Allison Division, General Motors Corporation; Prof. J. R. Markham, FIAS, Director, Naval Supersonic Laboratories, Massachusetts Institute of Technology; Paul J. Frizzell, Vice-President, Fairchild Engine and Airplane Corporation; R. C. Sebold AFIAS, Vice-President—Engineering, Consolidated Vultee Aircraft Corporation; Dr. Harold Von Neufville Flinsch, Dean, School of Engineering, Mississippi State College; and L. A. Hyland, Vice-President, Bendix Aviation Corporation.

Members appointed as supernumeraries are: Edward G. Uhl, MIAS, Vice-President—Engineering, The Glenn L. Martin Company, and L. E. Linde, Executive Vice-President for Defense Products, Westinghouse Electric Corporation.

Turboprop Test Program Announced

A test program directed toward obtaining operation service test data of turboprop-powered aircraft is being conducted by the USAF Air Research and Development Command, according to a recent announcement. The specific objectives of this program are (1) to accumulate maximum flying time in the minimum elapsed time and (2) to acquire knowledge of operational techniques for turboprop aircraft by establishing a routine operation and relying upon standard handling and service facilities as much as possible. The program is also expected to establish adequate controls for collecting pertinent data on technical difficulties, maintenance problems, supply consumption, and reliability in conforming to planned flight schedules.

As part of this turboprop research program, seven cargo-carrying aircraft (viz., two C-97's, two C-121's, one C-124, and two C-131's) are being modified. The C-97's, C-121's, and the C-124 are being outfitted with Pratt & Whitney T-34 turboprop engines by Boeing Airplane Company, Lockheed Aircraft Corporation, and Douglas Aircraft Company, Inc., respectively. The two C-131's are being modified with Allison T-56 turboprop engines. The first of these modified aircraft is expected to be flying the early part of this year.

The aircraft will first undergo tests to demonstrate airworthiness and suitability of flight. Upon the successful conclusion of this phase of the program by ARDC, maintenance experience, supply requirements, and other operation data on these aircraft will be secured by the Military Air Transport Service and the Strategic Air Command through their use in normal operation. The results of these tests will be disseminated throughout the Air Force and to commercial aircraft industries and air lines.

Necrology

James W. Adams

James Wendell Adams, MIAS, Consulting Engineer in airport construction, design, and maintenance, suffered a heart attack and died at his home on December 15. Funeral services were held on December 19.

Mr. Adams, who was born in Albany, N.Y., on November 15, 1896, received a Civil Engineering degree from Rensselaer Polytechnic Institute in 1925. Between his graduation from R.P.I. and 1929, he worked with The Foundation Company and with the Borough of Mountain Lakes, Mountain Lakes, N.J.

In 1929, he began an association with Curtiss-Wright Corporation that continued until 1945, except for a 14-month period in 1941–1942 when he was with the Airport Development Program of Pan American World Airways, Inc. Between 1929 and 1941 he was with Curtiss-Wright's Airports Division as Chief Engineer, and from 1942 until 1945 he was with that corporation's Propeller Division as an Engineer with the Defense Plants Department. He resigned from Curtiss-Wright in 1945 and for the next 2 years was with McLaughlin-Carr Associates in airport design and construction. He set up his own offices as Consulting Engineer about 6 years ago.

Mr. Adams is survived by his wife, Iva; two sons, Cpl. James W., Jr., USA, and Robert B.; a daughter, Carolyn I.; and a brother and sister.

News of Members

▸ **Ralph F. Baxter** (M), Project Engineer, Aircraft Division, Rheem Manufacturing Company, received the American Ordnance Association's James L. Walsh Memorial Award for his paper on "A Discussion of the Operation and Maintenance Problems of Complex Weapons." This paper was judged to be the best one submitted in the recent AOA-sponsored national contest.

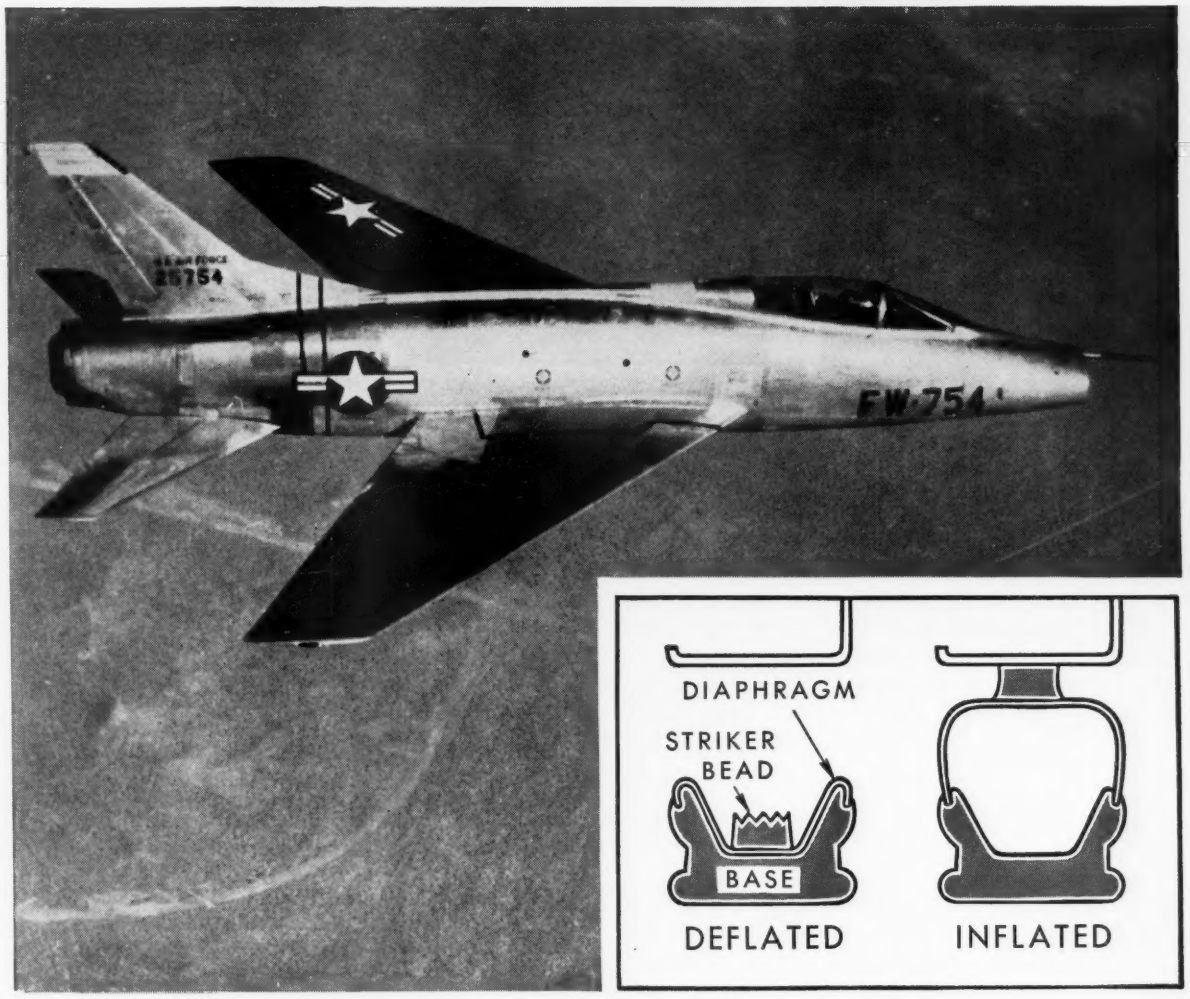
▸ **Charles H. Colvin,** IAS Fellow and Founder Member, has announced the incorporation of Colvin Laboratories and its new address. Effective the first of this year, all operations of Colvin Laboratories, Inc., are located at 364 Glenwood Ave., East Orange, N.J., with Mr. Colvin as President and General Manager and Julian H. Sano as Vice-President and Chief Engineer. The telephone number is ORange 7-1221. The services and products of the organization remain the same.

▸ **Rear Admiral Luis de Florez,** USN (Ret.) (F), Chairman of the Board, The de Florez Company, Inc., was recently named to serve on the Executive Committee of Flight Safety Foundation, Inc.

▸ **Frank W. Fink** (F), Chief Engineer, San Diego Division, Consolidated Vultee Aircraft Corporation, is the 1954 Vice-President—Aircraft of the Society of Automotive Engineers.

(*Continued on page 47*)

RESEARCH KEEPS **B.F.Goodrich** FIRST IN RUBBER



Low-pressure seal prevents high altitude blowouts

BUBBLE type canopies on fast military planes like North American's Super-Sabre had to be safely pressurized at altitudes of 8 miles or higher. Ordinary inflatable seals between the bubble and cockpit would often blow out from the effect of low pressures on the outside, high pressures on the inside.

B. F. Goodrich engineers were called in on the problem. A really effective seal, they believed, should operate with low pressure and stretch very little or not at all. Less stretch would mean less strain. They worked out a seal with a U-shaped solid rubber base. A rubberized fabric diaphragm nested inside the base simply *lifts* when inflated. (See diagram above). It works like blowing up a paper bag—low pressure gives full expansion with practically no stretch. Dangerous stretching of tube wall (like blowing up a toy balloon) is eliminated.

The new inflatable strip seal works almost instantly. Even at minus 65° it inflates with less pressure than ordinary seals needed at room temperature. There are other advantages. It resists wear and damage better than ordinary seals. It fits complex curves better. It seals and unseals faster. Sliding wear and scuffing are minimized.

The new B. F. Goodrich seal is now in use on more than a dozen makes of planes, including latest jet fighters and bombers.

Other B. F. Goodrich products for aviation include: tires, wheels and brakes; De-Icers; heated rubber; Pressure Sealing Zippers; fuel cells; Rivnuts; accessories. *The B. F. Goodrich Company, Aeronautical Sales, Akron, Ohio.*

B.F.Goodrich
FIRST IN RUBBER

President
J. L. Atwood
President
North American Aviation, Inc.

Vice-President
W. A. M. Burden
Partner
William A. M. Burden & Company

Vice-President
J. W. Larson
Chief Engineer
Convair
Fort Worth, Tex.

IAS Officers for 1954

Staff Officers for 1954
S. Paul Johnston, Director

Robert R. Dexter, Secretary

Joseph J. Maitan, Controller

Vice-President
E. T. Price
President
Solar Aircraft Company

Vice-President
E. S. Thompson
Manager of Contracts
General Electric Company

Treasurer
Elmer A. Sperry, Jr.
Owner
Sperry Products, Inc.

American Honorary Fellow
Preston R. Bassett, President, Sperry Gyroscope Company Division, The Sperry Corporation

Honorary Fellows for 1953

Honorary Fellows shall be persons of eminence in aeronautics and are elected by the Fellows and Honorary Fellows of the Institute residing in the United States. Not more than one person residing in the United States, nor more than one person residing in a foreign country, may be elected as Honorary Fellows in any one year.

Foreign Honorary Fellow
Sir William Farren, Technical Director, A. V. Roe & Company, Ltd., England

Fellowships in the Institute

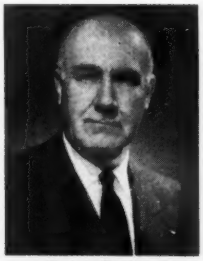
Fellows of the Institute of the Aeronautical Sciences shall be those who have attained a position of distinction in aeronautics and made notable and valuable contributions in one of the aeronautical sciences or aeronautical engineering.

Presented for 1953 to

Myron G. Beard
Chief Engineer
American Airlines, Inc.

L. P. Coombes
Chief Superintendent
Aeronautical Research Labs., Australia

Fred N. Dickerman
Chief Engineer
Chance Vought Aircraft Inc.



E. M. Powers
Vice-President—Engrg.
Curtiss-Wright Corporation

Perry W. Pratt
Chief Engineer
P. & W. Aircraft Div.
United Aircraft Corp.

Norbert E. Rowe
Technical Director
Blackburn & General Aircraft Ltd., England

Maurice Roy
Director, Office National d'Etudes et de Recherches Aeronautiques, France

E. E. Sechler
Prof. of Aeronautics
California Institute of Technology

E. C. Wells
Vice-President
Engineering
Boeing Airplane Co.

Carlos Wood
Chief Prelim. Design Engr.
Santa Monica Plant
Douglas Aircraft Co., Inc.

I.A.S. Awards and

Capt. Charles F. Gell (MC), USN, Aviation Medicine Acceleration Lab., NADC, Johnsville, Pa.

The John Jeffries Award

This award honors the memory of Dr. John Jeffries, an American physician, who, with Blanchard, the French balloonist, made the first aerial voyage across the English Channel in 1785 and on a previous voyage made the earliest recorded scientific observation from the air. This award, which has an honorarium of $200, was established by the Institute in 1940 to give recognition to the importance to aviation of scientific endeavor in the field of medicine.

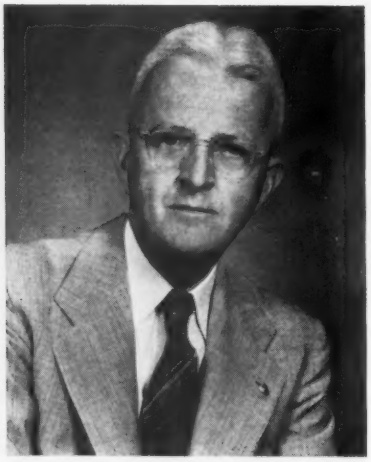
Presented to CAPT. CHARLES F. GELL (MC), USN

"For outstanding contributions to the advancement of aeronautics through medical research."

Captain Charles F. Gell (MC), USN, has been cited for investigations into physiological effects of radial accelerations on man which constitute fundamental contributions to the development of aeronautics. The resulting knowledge is proving valuable in giving adequate consideration to the human factors involved in developing design criteria for high-performance aircraft.

Since being assigned to the Laboratory in 1949, he has contributed in a large measure toward making the Human Centrifuge, located there, a tool for the continued study in the field of physiological response to radial accelerations. He has devised new experimental techniques that have aided in obtaining the greatest use from the centrifuge and other Laboratory equipment. One of these techniques is a quick-freeze process that permits the distorting effects of high-magnitude radial acceleration on small animals to be preserved intact for subsequent pathological examination.

Among other things that Captain Gell has investigated have been practical considerations involved in proving the potential of aircraft. In this regard, he has pioneered investigations into the use of the supine position for aircraft pilots and has been instrumental in conducting studies both on the centrifuge and in aircraft relative to the theoretical and practical effectiveness of this position.



Henry T. Harrison, Jr., Chief Meteorologist, United Air Lines, Inc.

The Robert M. Losey Award

Established in 1940, this award honors the memory of Capt. Robert Moffatt Losey, a member of the Institute and a meteorologic officer of the Air Corps, who was killed at Dombas, Norway, April 21, 1940, while serving as an official observer for the U.S. Army. He was the first officer in the service of the United States to die in World War II. This award carries an honorarium of $200.

Presented to HENRY T. HARRISON, JR.

"In recognition of outstanding contributions to the science of meteorology as applied to aeronautics."

Henry T. Harrison, Jr., has long been considered a stabilizing force in the field of aeronautical meteorology and has contributed greatly to the standard of air-line meteorology in the United States. To him is given a large part of the credit for the high standard of meteorological performance in the operation of United Air Lines and in the maintenance of excellent safety records.

Mr. Harrison was one of the air-line meteorologists who as early as 1941 identified the pre-cold frontal squall line and outlined its characteristics. This concept has been highly important in the last year or so in predicting tornadoes and other severe local storms of concern to aeronautics. In addition, he has done excellent work on the subject of hail forecasting and has made valuable studies of the jet stream and clear air turbulence.

He has authored numerous articles and reports dealing with aeronautical meteorology and has served on various committees concerned with meteorological problems in aviation. A member of the Byrd Antarctic Expedition, he was awarded the Congressional Medal for polar exploration.

Honors for 1953

Ernest G. Stout, Staff Engineer, Consolidated Vultee Aircraft Corporation.

Dr. Donald Coles, Research Fellow, California Institute of Technology.

The Sylvanus Albert Reed Award

For a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations which have had a beneficial influence on the development of practical aeronautics.

The late Dr. S. A. Reed, designer of metal aircraft propellers and a Founder Member of the Institute, made an endowment to the Institute in 1933 to provide an annual award with a certificate and honorarium of $250. The recipient of this award is chosen by the ballot of the American Honorary Fellows and Fellows of the Institute.

Presented to ERNEST G. STOUT

"For his analytical and experimental contributions to the design and development of high-speed water-based aircraft."

Ernest G. Stout is responsible for Naval aircraft research and development at Consolidated Vultee Aircraft Corporation and is Chairman of the NACA Subcommittee on Seaplanes. Since receiving his degrees from New York University in 1935, he has been principally engaged in theoretical analysis, experimental research, and full-scale development of advanced water-based aircraft.

Mr. Stout pioneered in the conception and development of successful experimental techniques and equipment for the investigation of complicated hydrodynamic phenomena for which he received The Lawrence Sperry Award in 1941.

Recognizing the increasingly critical nature of the seaplane problems and not accepting the general belief that there were inherent penalties in that form of operation, he applied the new research methods to a development concept that has altered radically the form of water-based aircraft and has brought them continually closer to the ideal aerodynamic configuration. During the postwar period, this program accented high-speed development and achieved the world's first turboprop seaplane and, more recently, the world's first delta-wing water-based aircraft.

The Lawrence Sperry Award

For a notable contribution made by a young man to the advancement of aeronautics.

This award was endowed in 1936 by the sister and brothers of the late Lawrence Sperry, pioneer aviator and inventor, who died in 1923 at the age of 31. It provides an annual certificate of citation and an honorarium of $250 to the recipient selected by the Board of Award.

Presented to DR. DONALD COLES

"For fundamental contributions to the understanding of supersonic skin friction."

Dr. Donald Coles, a 30-year-old native of St. Paul, Minn., received his bachelor's degree from the University of Minnesota in 1947. At California Institute of Technology, he accomplished his graduate work and received his master's degree in 1948 and his Ph.D. degree in Aeronautics and Mathematics last June. He was made Research Assistant at Cal-Tech's Hypersonic Wind Tunnel in 1948 and 2 years later was appointed Senior Research Engineer at the school's Jet Propulsion Laboratory. In 1953, he was named to his present position.

The contributions made by Dr. Coles to the understanding of supersonic skin friction have been acclaimed by scientists and engineers working in the field of skin friction. Material on Dr. Coles' work is only now being published. His Ph.D. thesis, "Measurements in the Boundary Layer on a Smooth Flat Plate in Supersonic Flow," is appearing *in toto* in three Jet Propulsion Laboratory reports. One of his papers, "The Problem of the Turbulent Boundary Layer," is scheduled to appear in the Swiss publication *Zamp* the early part of this year. Two additional manuscripts on his work are currently being prepared by Dr. Coles; their publication, however, has not as yet been definitely set.

Newly Elected Members of the Institute Council

Eastern Area

G. W. Baughman
Engrg. Staff Specialist
Lockheed Aircraft Corp.
(Marietta, Ga.)

W. M. Duke
Asst. Director—Tech.
Cornell Aeronautical
Lab., Inc.

Central Area

R. N. DuBois
Chief Prod. Engr.
Aircraft Division
Ford Motor Co.

H. F. Waring
Chief Engineer
Military Aircraft
Cessna Aircraft Co.

Western Area

J. E. Barfoot
Project Engineer
Boeing Airplane Co.
(Seattle)

W. T. Immenschuh
Executive Engineer
Engineering Division
Ryan Aeronautical Co.

Council Members

(Left) P. R. Bassett
President
Sperry Gyroscope Co. Div.
The Sperry Corporation

(Right) M. G. Beard
Chief Engineer
American Airlines,
Inc.

(Bottom left)
V. E. Carbonara
President &
General Manager
Kollsman Instrument Corp.

(Bottom Right)
R. C. Sebold
Vice-President
Engineering
Convair (San Diego)

J. A. Herlihy
Vice-President
Engrg. & Maintenance
United Air Lines, Inc.

E. M. Powers
Vice-President
Engineering
Curtiss-Wright Corp.

(*Continued from page 40*)

▸ **Harold R. Harris** (F), President, Northwest Airlines, Inc., was granted an indefinite leave of absence from the company for reasons of ill health. This action was taken by the Board of Directors on January 11. During Mr. Harris' absence, Malcolm S. Mackay, Vice-President—Continental Division, is serving as Chief Executive Officer of the company.

▸ **Frank W. Hulse** (M), President, Southern Airways, Inc., has been elected to the Board of Directors of the Conference of Local Service Airlines of the United States.

▸ **Vice Admiral Emory S. Land,** USN (Ret.) (F), has resigned as President of Air Transport Association of America. This was effective on last December 31. In announcing his resignation from ATA, Admiral Land indicated that he would tender his resignation to Air Cargo, Inc., and Aeronautical Radio, Inc., as President and Board Chairman, respectively. Admiral Land is continuing his association with aeronautics in the capacity of Consultant.

▸ **Captain William W. Moss** (M), Pan American World Airways, Inc., has been appointed Assistant Chief Pilot, Training, of the company's Atlantic Division.

▸ **G. W. Newton** (M), Chief, Engine Test Facility, Arnold Engineering Development Center, is serving as the 1954 Vice-President—Aircraft Powerplant of the Society of Automotive Engineers.

▸ **W. A. Patterson** (M), President, United Air Lines, Inc., was recently appointed by President Eisenhower to serve on the Commission on Judicial and Congressional Salaries.

▸ **Robert W. Rummel** (M), Chief Engineer, Trans World Airlines, Inc., has been elected Vice-President—Air Transport for 1954 of the Society of Automotive Engineers.

▸ **J. Carlton Ward, Jr.** (M), President, Vitro Manufacturing Company, has been elected Chairman of Flight Safety Foundation, Inc.

▸ **Captain P. V. H. Weems,** USN (Ret.) (F), Partner, Weems System of Navigation, has been awarded the Magellanic Premium for 1954 by the American Philosophical Society of Philadelphia. Captain Weems was selected to receive this award "for his invention of methods and instrument for celestial navigation."

Rear Admiral Calvin M. Bolster, USN (Ret.), FIAS, retired from active Naval duty on January 1. He had been serving since August, 1951, as Chief of Naval Research, Office of Naval Research. A 1919 graduate of the U.S. Naval Academy, he received an M.Sc. degree in Naval Architecture in 1922 and an M.Sc. degree in Aeronautical Engineering in 1936. Admiral Bolster, who is both a heavier-than-air and lighter-than-air (airship) pilot, served on various surface ships, including battleships and aircraft carriers, and on rigid airships, including the U.S.S. "Los Angeles" and U.S.S. "Macon." In June, 1935, he was designated for "Aeronautical Engineering Duty Only."

William Littlewood, FIAS, Vice-President—Engineering, American Airlines, Inc., has been inducted as the 1954 President of the Society of Automotive Engineers, succeeding Robert Cass, of White Motor Company. Mr. Littlewood, who delivered the IAS Wright Brothers Lecture in 1952, was the recipient of the SAE Wright Brothers Medal in 1935 for the presentation of the year's outstanding technical paper on aeronautical engineering. With American Airlines since 1930, he was appointed Chief Engineer in 1933 and to his present post in 1934.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of IAS members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

John A. Bachman (TM), Aerodynamics Engineer, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation. Formerly, Aerodynamics Engineer, Chase Aircraft Company.

Edwin Plato Bernat (M), Lecturer in Mechanical Engineering; University of Sheffield, England. Formerly, Assistant Professor in Mechanical Engineering, Polish University College, London, England.

Harold J. Carrick (M), Chief Advisor, International Field Office, Civil Aeronautics Administration, Tokyo, Japan. Formerly, Deputy Chief, Technical Assistance Division, CAA, Washington, D.C.

U. A. Cotecchia (M), see U. A. Coty. (Mr. Cotecchia's surname was recently changed by the courts of the State of Michigan to Coty.)

U. A. Coty (M) (name recently changed from U. A. Cotecchia), Research Engineer, Guided Missiles Division, Lockheed Aircraft Corporation. Formerly, Research Associate, Willow Run Research Center, University of Michigan.

I. H. Culver (M), now Manager, Engineering Experimental Design, Missile Systems Division, Lockheed Aircraft Corporation.

Private Philip M. Fleiss, USA (TM), 9th Infantry Division, Fort Dix, N.J. Formerly, Structures Engineer, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation.

Ensign George F. Fritz, USNR-R (TM), ATU 200, NAAS, Kingsville, Tex. Formerly, Naval Cadet, NAAS, Barin Field, Foley, Ala.

James E. Hannigan (TM), Extended Active Duty as Second Lieutenant, USAF. Formerly, Weights and Balance Engineer "B," Boeing Airplane Company.

Jacques A. F. Hill (M), Naval Supersonic Laboratory, Massachusetts Institute of Technology. Formerly, Research Department, United Aircraft Corporation.

Private John L. Martz, USA (TM), Co. "D," 37th Armd. Inf. Bn., Div. Arty, 3rd Armored Div., Fort Knox, Ky. Formerly, Aerodynamic Development Engineer, Wind Tunnel Branch, Wright Air Development Center, Wright-Patterson AFB, Ohio.

Charles O. Miller (TM), Staff Cockpit Design Engineer, Chance Vought Aircraft, Inc. Formerly, Regulus Project Test Pilot, United Aircraft Service Corporation. Edwards AFB, Calif.

Donald W. Richardson (TM), Senior Aerodynamics Engineer, Propeller Division, Curtiss-Wright Corporation. Formerly, Aeronautical Engineer, Chase Aircraft Company, Inc.

F. S. Shaw (M), Superintendent, Structures and Materials Division, Aeronautical Research Laboratories, Melbourne, Victoria, Australia. Formerly, Associate Professor, Polytechnic Institute of Brooklyn, New York.

Major Walter C. Stewart, Jr., USMC (TM), Graduate Student in Aeronautical Engineering, Princeton University. Formerly, Captain, USMC.

(*IAS News Continued on page 88*)

Honors Night Dinner Address

by

CHARLES A. LINDBERGH

Charles A. Lindbergh receiving the Daniel Guggenheim Medal from Harry F. Guggenheim.

Photo (left) Copyright by IAS

Guest Editorial

"The receipt of the Daniel Guggenheim medal would be a great honor under any circumstance. It has unusual significance to me because I knew and admired the man on whose name it was founded. I met him when I was a young pilot, 26 years ago last summer, at his home on the north shore of Long Island—in that gray-rock building which overlooks the Sound and which was later donated to the Institute of the Aeronautical Sciences.

"I met him at a time when most people looked with skepticism upon aircraft, when transcontinental passenger routes were no more than enthusiasts' ideas, and when transoceanic air schedules were a part of our vaguer dreams. Even at that time, Daniel Guggenheim had faith in the future of aviation—partly reasoned—partly intuitive. He had the courage to say so and the confidence to back up his beliefs with a fund of $3,000,000, devoted to the promotion of aeronautics and directed by his son, Harry—a naval aviator of World War I. Several years later, again with vision far ahead of the period, he financed Robert Goddard in those pioneering rocket experiments that were carried out on the plains of New México.

"Many of us ... have watched the ideas and the dreams of a quarter century back come true. We have seen the confirmation of Daniel Guggenheim's beliefs. Airplanes carry passengers by millions and compete with trains for first-class mail. Air routes over continents and oceans spider-web the earth. In fact aviation has been so successful that, together with other

branches of modern science, it has revolutionized the environment of man.

"We dwell in a smaller world, by the scale of clocks; we are more vulnerable to our enemies, more accessible to our friends; we tap previously distant sources of supply. Science has revalued geographical locations, increased the density of populations, and offered its rewards to new knowledges and trades. The houses we own, the meals we eat, the tensions we feel, the skills we teach differ from those of our forefathers in fundamental ways. Ideals, wealth, and power are all in a state of flux.

"Human history contains no comparable environmental change. In this fact, our pride is countered by our apprehension. Current experience combines with biological knowledge to warn us that a radical change in environment requires an adjustment on the part of life which is fascinating, tremendous, and often terrible. It is in relation to our modern environment that I should like to discuss aviation,...for I think we are in danger of confusing problems of long-term and of short-term survival.

"When the art of flying was very young, most of us thought that men on wings would soar over mountains and oceans to bring countries close together in peaceful understanding. We assumed that easy contact between peoples would simplify diplomacy and decrease war. Now, at the end of the first half-century of engine-driven flight, we are confronted with the stark fact that the historical significance of aircraft has been primarily military and destructive. Our bombs have wiped out, in minutes, an inheritance of life and labor which centuries created. Aviation is having its greatest effect on the force-influence of nations and factors of survival, while diplomatic relationships are floundering in a strange new framework of power, time, and space.

"With hindsight, we see that our early enthusiasm over the discoveries of science and the conquest of the air blinded us to natural laws that govern the conduct of men. All our scientific progress has not changed the fact that God made life on earth prolific, competitive, selective. When we overlook such basic laws, we are likely to extrapolate short-term trends into false utopias of brotherhood and peace.

"The fact that modern communication has brought unity to our states of North America, and that people everywhere are now more accessible to each other, does not reverse the rock-old tendency of life to diverge and compete in form and values. Science has increased the size of evolutionary groups, set up new combinations, and added tremendously to the power of their tools; but one sees little indication that strife has been reduced. From wood-wheeled cart to turbine airplane, men have always used their inventions to advance their beliefs, trade, and sovereignty—alternating their support, according to their purpose, between forces that unite and forces that divide.

"In recent years, we in America have spent an alarming amount of thought and energy on war. We find ourselves in the position, encountered so often through the ages, of having to rely on arms to maintain peace and protect the way of life that we believe in. Like those of Rome, our frontiers have expanded, while the nations allied with us to maintain them depend largely on our strength.

"We know that defensive forces cannot cope with atomic bombs and supersonic missiles; therefore our security rests in the decentralization of vital targets and in our ability to deliver an immediate and crippling attack. We must spread out our factories, and we must keep in being fleets of aircraft which can strike an enemy more effectively than he can strike at us. Science has destroyed the old framework of ground-marked space and wheel-marked time which let other generations prepare for war after hostilities had started.

"A survey of world conditions and existing trends indicates that we must be a nation constantly more versed in scientific, industrial, and military techniques, organized to an efficiency untouched in ages past. The tremendous effect on our environment is obvious. We are likely to be more regimented, live more indoors with artificial lights and climates, consume more preserved foods, develop our minds out of proportion to our bodies, and choose the father or mother of our children according to the ideals that ensue from such a life. Birthrates will adapt themselves to new surroundings, and even hereditarily we will become a different people.

"Man has always had a tendency to complicate his life with technical knowledge and material devices. Since the mechanistic age began, we have allowed ourselves to become increasingly bound to a régime required by its training and encouraged by its products. Our population has shifted from farm to factory in order to better tend machines, administer commerce, and gain the conveniences of city life. This tendency, originally fostered by intellectual curiosity and economic reward, is now accelerated by military necessity and our instinct for survival. In a competitive world, life and freedom must be backed by strength.

"But survival has a time dimension that says that power consists of more than strength of arms. Short-term survival may depend on the knowledge of nuclear physicists and the performance of supersonic aircraft, but long-term survival depends alone on the character of man. Our scientific, economic, and military accomplishments are rooted in the human quality that produces them. In the last analysis, all of our knowledge, all of our action, all of our progress succeeds or fails according to its effect on the human body, mind, and spirit. While we concentrate our attention on the tools of economics and war, we must not neglect the basic means of surviving, the basic reason for survival, man himself.

"What will this modern environment of ours create in the future character of man? Here, rather than in the atom, is the power that will establish our wisdom and decide our fate. And here we pass beyond clear-cut scientific frontiers. Our clocks, weights, measures, and mathematics become inadequate when we discuss

the basic qualities of man. We can mark down human efficiency in figures of mass production, but how are we to evaluate mass production, say in such spiritual elements as faith and joy, compassion and courage? We know when we have won a victory in war, but how can we subtract our losses and find the product of that victory in terms of future cultural and hereditary strength?

"Human character consists of a fluctuating balance of qualities that we attempt to describe with such words as 'physical,' 'mental,' 'emotional,' 'spiritual.' Emphasis or repression of any one of these qualities has a major effect on all the rest, and the result can carry on for generations. As this is true with individuals and families, it is true with communities and nations, the one reacting on the other, slowly, while conditions change with years. We speak of the physical stamina of Russia, the rationality of France, the vivaciousness of the Italian, or of India's mysticism.

"We think of peoples noted for their tendency toward war or peace, regimentation or individualism, industry or agriculture; and in each case the overemphasis of one quality results in weakness in another. A regimented Germany overruns an individualistic France, to be hurled back by the agrarian endurance of Russia, and decimated by America's industrial production. But the physique of Russia lacks the mentality for freedom, while the increasing industrialism of the United States has left many men and women questioning the system that creates it. In the time dimension, survival depends upon the balance we maintain; strength is catabolic without wisdom for direction, and the sermons of Christ become as essential as the steel of Bessemer to our power.

"Man is born with qualities of body, mind, and spirit. No system can maintain the utmost power unless it gives all his faculties free play. Most of us remember when the requirements of living enforced a more balanced life. Not many years ago, the efficiency and specialization demanded of us today were impossible. As a lawyer, my father harnessed a horse to carry on his business. As a young pilot, I unlashed my wings from fence posts and pulled through my own propeller. But my father and I knew the feel of rain and the smell of ground, and there was time for our thoughts to wander. When night came, our muscles put our brains to sleep.

"Now, modern standards require an efficiency that immobilizes the muscles and the senses while it overactivates the brain. Think how tightly we bind our flesh to chair and bench in order to support our intellect's excursions! We insulate man more and more from his old environment of earthy weather. We design him into closed automobiles, commuters' trains, and air-conditioned buildings. Yet we all know that lethargy of body slants the reason of the mind. In aviation, this trend has been particularly clear. As speed and completed schedules improved, pilot and engineer alike lost touch with the hayfield's sun. The yielding sod of early days gave way to concrete aprons, while open cockpits were streamlined into fuselages until our cheeks no longer felt the turbulence of air.

"In aviation, our old, carefree fascination with the art of flight has metamorphosed into a responsibility for the welfare of mankind and the security of our American people. On the one hand, it has become our mission to maintain rapid intercourse between all nations. On the other, it is our duty to construct the world's greatest military force. To our skill is entrusted the terrifying power of the atom bomb. Our aircraft have to navigate with extreme accuracy, over long distances, at projectile speeds, and in stratospheric altitudes.

"This responsibility involves a life of dedication and discipline, for the 'know-how' it requires is immense. Youth must specialize in technical training. Daylight hours of adult years must be spent beside machines, drafting boards, and desks. Here, we meet the basic question of how deeply and how long man can consecrate himself to his machines without losing the human qualities essential even to effective consecration.

"American aviation has accepted the responsibility for material power. From the standpoint of short-term survival, the confidence placed in our science and industry has been justified through the performance and the numbers of our aircraft. But our very success in the field of material power silhouettes problems of human power which confront us. War, strikes, and political unrest have flamed on all our speed-compressed horizons. From the standpoint of long-term survival, what is our régime of life doing to our people? As in other fields of modern enterprise, our responsibility for human power is still too vague of concept.

"During decades of industrial development, western man has taken himself for granted, while he concentrated his attention on his material creations. He now wakes rather suddenly to find his security dependent on the machine organization he has built, with his civilization threatened by its products. He comes to the increasing realization that he has not kept inward pace with his outward actions.

"This mid-century generation we represent stands on amazing accomplishments but faces alarming problems. We have wiped out a city with a single bomb, but how can we use this fact to heighten our civilization? We build aircraft by the tens of thousands in our factories, but what will our factories build in the character of their personnel—not only in our generation, but in our children's, and their children's? We tie all countries close together, put each doorstep on a universal ocean, but how are we to direct these accomplishments to improve the basic qualities of life? In emphasizing force, efficiency, and speed, are we losing a humility, simplicity, and tranquility without which we cannot indefinitely hold our own, even in worldly competition?

"These are the problems of human power, of long-term survival upon earth. We have shown what man can make of science. Now it is a question of what

(*Continued on page 87*)

General Design Aspects of Flight Refueling

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THE TECHNIQUE OF FLIGHT REFUELING augments two of the basic principles of warfare: range and mobility. The foundation of the Air Force as a separate service rests on its inherent superiority in these two principles. Therefore it is not surprising that flight refueling occupies such a peculiarly conspicuous position in the weapon systems picture.

In the July 9, 1923, issue of *Aviation*, the following item appears:

> "An airplane in flight was refueled for the first time in the history of aviation near San Diego, California, on June 25.
>
> "Flying at a speed of 90 m.p.h., Lts. Hines and Seifert guided their craft above that flown by Capt. Lowell Smith and Lt. John P. Richter. The fuel ran down a 40-ft. steel wire encased rubber hose and within 2 min. the feat was done."

Was it considered a stunt by them? John Richter, now Colonel, USAF (Ret.), states that during World War I, the Spad airplane had only 20- to 40-min. endurance over the front lines. Pilots often wished for a means of refueling without having to return to base. In this statement is expressed the idea of refueling in flight in order to increase the effectiveness of the patrol, a present-day tactical concept. Colonel Richter states that, on the day the St. Mihiel offensive started, he had to fly nine sorties because his airplane's endurance was so limited. Yet, on August 27–28, 1923, when he and his teammates broke the world's endurance speed and distance records during a 37-hour, 15-min. flight, this was termed a stunt in some quarters.

But these Rockwell Field pilots were not through demonstrating the military potential of flight refueling. On October, 25, 1923, this same quartet, aided by Capt. R. G. Ervin and Lt. O. R. McNeel, demonstrated the mobility that flight refueling gave the Air Service. Smith and Richter flew from Sumas, Wash., on the Canadian border to Tia Juana on the Mexican border, nonstop, having been refueled in flight twice enroute by tanker planes temporarily based at Eugene, Ore., and Sacramento, Calif.

Major H. H. Arnold, the base commander, was an ardent supporter of these early experiments. General Patrick, Chief of the Air Service, commended the fliers for both the endurance and the border-to-border flights. It is believed that these records show that the military significance of flight refueling was well appreciated by these military airmen of an earlier day.

Fig. 1 shows the system in use at the time. It is interesting to note that neither pilot could see the point of contact between the two airplanes. The formation position was awkward to fly, and a collision hazard existed. Both planes were DH-4's, so their formating compatibility was good. The hose was raised and lowered with the aid of a cable and a tow-target reel.

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No hose reel was used. The hose was coiled around the operator's feet in the rear cockpit. The tanker had a fuel shut-off valve, and the end of the hose had a shut-off valve, both manually operated. Nonetheless, the receiver operator was frequently drenched with fuel when inadvertent disconnects occurred because of gusty flight conditions. Although the standard DH-4 had a radio installed, perhaps it had been removed to permit the installation of the special flight refueling equipment, for there is no record to show that a radio was used for either interplane or air-to-ground communication for any of the flights. Colonel Richter states that, at first, all personnel were extremely concerned about fire and explosion hazard, but when nothing happened after the frequent drenchings, they concluded that the operation was pretty safe on this score.

While on the subject of firsts, not only fuel but oil, water, and food were received in the rear cockpit and dispensed to appropriate parts of the airplane. A manually operated air pump was connected to a master distribution valve. This pressurized the respective service reservoirs mounted behind the rear cockpit and forced the various liquids into the proper engine systems. It should be mentioned here that Colonel Richter's experience prior to entering the Air Service was as a locomotive test engineer with the Santa Fe Railroad. He was a man not easily befuddled by a collection of pumps, tanks, valves, and gages surrounded by wind, noise, and grime.

When another group of fliers demonstrated this new invention at an air show at Kelly Field in November of the same year, tragedy struck. The airplanes collided, and the first of only two known fatal accidents due to flight refueling occurred.

For the next few years our nation was not concerned with any immediate enemy. Five years passed before flight refueling was resurrected in 1929 by Major Spaatz, Captain Eaker, Lieutenants Quesada and Halverson, and Staff Sergeant Hool in order to establish a new world's endurance flight. They remained air-borne for 150 hours. The equipment was almost a copy of that used in 1923, so that little development was achieved by this demonstration. However, because of the fact that the receiver was a monoplane and the tanker was a biplane, a new technique for flight refueling was evolved which the Air Force has been scientifically exploring in the last few years. This is the technique known as "descent refueling," which enables a relatively slow tanker to keep up with a relatively fast receiver by conducting the refueling operation in a continuous descent. The officers recommended the development of an automatic fuel shut-off valve at the end of the hose, although this time there were four men who could alternate getting drenched, this despite the fact that, benefiting from the 1923 experience, they had taken a rubber hat, coat, and boots aloft with them.

Following the flight of the "Question Mark," the art of flight refueling caught the attention of many people in many lands. It is known that the Germans, the French, and the English all conducted experiments. In 1932 Squadron Leader Atcherly of the RAF patented a crossover method for making contact between two airplanes for the purpose of flight refueling.

In England there was another who watched the RAF trials. His name was Alan Cobham. He had pioneered the Empire air routes to Africa, Australia, and India. He knew the miserable condition of airports of that day and knew of the inconveniences suffered in obtaining fuel and lodgings at these airports. He was to spend the major portion of his life to the present day in the development of flight-refueling systems.

Cobham watched as Atcherly also developed a shut-off valve in the coupling so that fuel would not be spilled when contact was broken. When Cobham started his trials, he was confronted by the necessity of getting around Squadron Leader Atcherly's patent on the cross-over method. Cobham did this by developing the harpoon projectile method. In this contact method a trailing cable from the receiver airplane was engaged by a cable shot from the tanker airplane from a harpoon gun. After the two cables made contact, the hose was hauled from the tanker airplane into the receiver airplane and fuel was passed. Cobham's associate, P. R. Allison, developed an automatic shut-off valve and coupling so that inadvertent break-aways could be made without danger to either airplane or to the equipment. This development was exceedingly important, since it enabled Cobham to obtain an airworthiness certificate. With this he obtained commercial support for his venture and in 1934 organized his own company, Flight Refuelling, Ltd.

In 1939, a total of 15 commercial scheduled refueling flights were made between Southampton and New York using Cobham's equipment.

In 1942, Flight Refuelling, Ltd.'s equipment was installed by Wright Field with slight modification in a B-24 tanker and B-17 receiver. Characteristically, the Yanks added electric hydraulic power to the winch and reel operations, which had formerly been done manually. Seriously, the higher air speeds of the B-17 and B-24 forced this change. This equipment successfully

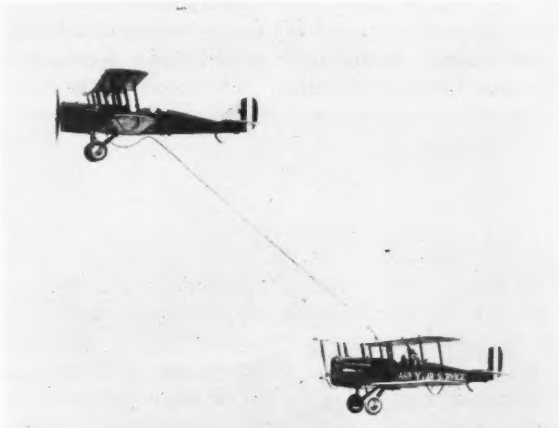

FIG. 1. Refueling in mid-air by Capt. Lowell H. Smith and Lt. John P. Richter, at Rockwell Field, Calif. They stayed in the air 4 days, using de Havilland planes.

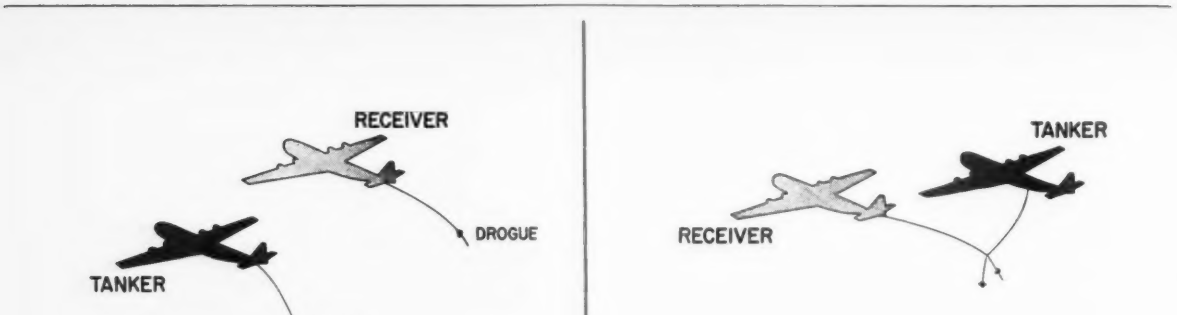

FIG. 2. Looped hose equipment.

passed Air Proving Ground tests in 1943. Of necessity another of Flight Refuelling, Ltd.'s developments had been the perfection of a manifold fuel system, which filled the various fuel cells in the receiver airplane from the single coupling point, shut off the flow of fuel gently when the tanks were full, and prevented the pressure of the gravity and dynamic head of fuel from being subjected to the individual fuel cells. This manifold fuel system was incorporated in the B-17 receiver. Fuel was transferred by force of gravity at an average rate of 120 gal. per min.

In 1944, the British Air Ministry called upon Flight Refuelling, Ltd., to convert a large number of Lancaster and Lincoln bombers for long-distance bombing by means of in-flight refueling. The success of the island-hopping strategy in the Pacific led to the abandonment of this project, as well as the B-17, B-14 project, but not before a substantial number of systems had been manufactured.

In 1946, the British company added a new technique. Trials were made over the English Channel between May and December at altitudes up to 20,000 ft. by day and by night. Rendevous between the tanker and receiver airplanes was accomplished by an adaptation of the Rebecca-Eureka radar equipment, which had been developed during the war for use in paratroop and glider operations.

Using the rendezvous technique and the equipment produced during the war, the British Ministry of Civil Aviation sponsored a series of eleven experimental flights from London to Bermuda in the summer of 1947. None of the commercial pilots in the receiver airplanes had had any previous experience in flight-refueling operations, nor was it necessary for the receiver airplanes to deviate from the agreed-upon course. Intercepts were made by the tankers between 200 and 500 miles off Santa Maria in the Azores, the tanker base.

So successful were the Bermuda trials that in the next test 15 roundtrips were made between February 4 and May 30, 1948, between London and Montreal. Refuelings took place approximately 500 miles west of Shannon and within 200 miles of Newfoundland. On the whole, the refueling trials were outstandingly successful from a technical standpoint. It was certainly proved that the quickest commercial service over long routes could be obtained by flight refueling, rather than requiring the air liner to land for fuel.

At this point in history, the U.S. Air Force, having experimented three times previously with flight refueling, adopted the technique as part of its standard operational procedure. In October, 1947, the Strategic Air Command requested the development of in-flight refueling to enable it to more successfully fulfill its basic mission requirements. Headquarters, USAF, promptly ordered Wright Field to proceed.

An entirely USAF development was initiated along the lines of what was known of the British equipment,

plus some information obtained from the National Council of Inventors (of America), relative to Squadron Leader Atcherly's cross-over contact patent. In the next few months, two B-29's were equipped at Wright Field with winches built by All-American Aviation Corporation for use in aerial pickup work. Successful cross-over contacts were made at altitudes up to 20,000 ft. by day and night.

On Wednesday evening, March 24, 1948, Headquarters informed Wright Field that it was necessary to demonstrate within the next 3 days that a B-29 could be refueled from another B-29. The Boeing Airplane Company's Wichita Division was alerted, and on Thursday afternoon, the writer, his Wright Field colleagues, and the test aircraft arrived at Wichita. Late Sunday afternoon, 440 gal. of a mixture of water and antifreeze solution were successfully transferred at a rate of 35 gal. per min. The contact itself had taken 52 min. to accomplish, and altogether the airplanes were in continuous contact for approximately 1 hour, 12 min. It was well worth the effort.

During the following week, congressional hearings were held to determine which Service would have the prime responsibility for delivery of the A-Bomb. The Air Force was able to state that it had successfully completed a refueling operation between two B-29's in flight and that this capability gave it a tremendous strategic potential. On Friday of that week Congress decided that the Air Force would have prime responsibility in delivery of the A-Bomb. As of this period, the Air Force has never relaxed its endeavors to continue the development of flight-refueling equipment.

As the test airplanes returned to Wright Field, the airplane that was bringing the first of a large order of Flight Refuelling, Ltd., equipment into this country was passed in flight. A large number of B-29's and B-50's were equipped by Boeing as tankers and receivers with this British equipment.

Fig. 2 shows this looped hose equipment in use. In the upper left sketch, the tanker is flying a left wing position from the receiver aircraft, and both are trailing cables. The receiver airplane's cable is trailed out straight by means of a windsock or drogue. The tanker's cable is trailed low by means of a weight known as a sinker. The tanker then crosses over to the right wing position which causes the two cables to engage. The remaining sketches show the drawing of the hose across to the receiver and the final break-away, which is done by paying out the hose from the receiver airplane until a fixed length of cable has been paid out, with a weak link incorporated in it. The weak link separates and the trailing components are rewound into their respective airplanes. Boeing Aircraft Company, in conjunction with the Wayne Pump Company, added a fuel transfer pump to the system. Even with the long hose necessary with the B-29's, a rate of 185 gal. per min. was achieved. American Rebecca-Eureka equipment was installed for rendezvousing.

Several notable flights were made using this equipment. In 1949, the Lucky Lady, Fig. 3, flew around the world in 4 days, being refueled four times in flight. It, too, was a demonstration of mobility. The Lucky Lady showed that an attack could be launched from the zone of the interior to virtually any place in the world within 48 hours, assuming that a strategic complex of tanker bases has been prepared in advance. This demonstration was not range extension in the combat sense, since the Lucky Lady could have made the same trip without flight refueling by landing at the very bases from which the tanker airplanes were based. However, the landing, ground refueling, and take-off operations would have consumed time and might have revealed the nature of the mission to the enemy. Surprise might have been lost.

A true range extension demonstration was given by another airplane in December, 1948. This airplane took off from Fort Worth, Tex., dropped its bombs near Hawaii, and returned to Fort Worth for a total mission of over 9,000 miles, having been refueled outbound and inbound near the Pacific coast from tankers also based at Fort Worth. Had this double-refueled mission been launched from one of our forward bases against an enemy, it would have been a true demonstration of the use of flight refueling to increase the effective combat radius of a bomber, an increase obtainable practically by no other means.

Fill the gap though it did, this equipment was a long way from being optimum in the B-29 aircraft. It had been designed originally for an air speed of 160 knots, and it was necessary to fly at 190 knots in order to refuel completely a B-29 or B-50 receiver aircraft. It was basically limited to low air speeds because the hose was being dragged through the air crosswise to the relative wind. Under the best conditions it took 4 min. to establish contact between the tanker and receiver aircraft. Skilled operators were required in both aircraft, and the refueling operator's position in the tanker aircraft was in an unpressurized compartment almost completely exposed to the elements. It was not adaptable to fighter refueling. Although this equipment is still in use as limited standard, the Air Force, coincident with the purchase of the British equipment, had immediately taken steps to develop a better system.

This development became known as the flying boom system and is illustrated in Fig. 4. To review this

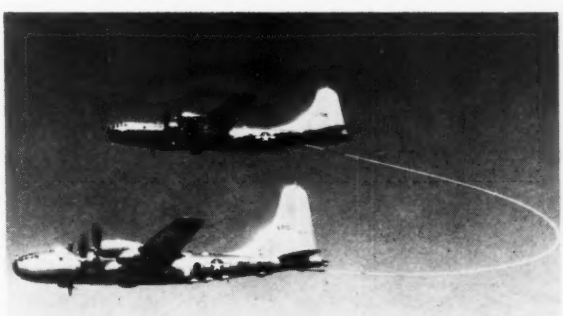

FIG. 3. The Lucky Lady II. Boeing B-50 (*lower*) is shown being refueled in flight by the Boeing B-29 (*above*) during a training mission over Arizona.

system briefly, it consists of a telescopic boom mounted in the tanker aircraft in such a way that the contact is made under the control of a boom operator, who manipulates the boom through the use of the ruddervators and guides the telescopic boom section into the receptacle on the receiver aircraft. Once contact is established, the boom in its design concept is freely telescoping, and it is not under the control of the boom operator or the receiver pilot in any way until the disconnect is made at the end of the refueling operation.

The advantages of the boom system over the old looped hose system are obvious. Contact is usually made in seconds. It can be used to refuel fighters. The relatively large diameter of the boom and its relatively short length permit high rates of fuel transfer. This means that the refueling operation can be completed more simply and in a shorter length of time. This equipment became operational late in 1949 and has undergone intensive detail development ever since. Flying boom equipment is now installed in large numbers of KB-29 and KC-97 tanker aircraft, and many aircraft have been equipped as receivers for use with this system—the B-50, B-47, B-52, and the F-84 airplanes. Mass flights across the Atlantic and Pacific have been conducted in the past 2 years. The boom is the standard USAF flight-refueling system. The great majority of all flight-refueling operations have been completed using this equipment.

What are the limitations of the boom equipment? Aerodynamically, there is a drag penalty since it is not stowed internally. In operating position it is depressed at an angle of approximately 30° to 45° to the relative wind. Thus it faces a definite Mach Number limit due to buffet. It is restricted mechanically in its angular operating limits. This narrows its operating envelope and requires a high degree of pilot skill to maintain the required close formation, especially during the latter portion of the refueling operation, when the receiver aircraft is reaching its maximum weight and becomes sluggish in handling characteristics. While in its design concept, the boom is freely telescoping; while in the contact position, this is not the case in practice. The pressure and mass rate of the fuel which is being delivered through the boom causes the boom to develop a certain rigidity along the telescoping axis. Unless means were incorporated to prevent it, it can be readily understood that, because of the pressure of the fuel, the boom would extend to its maximum length and remain there during the entire operation. The Boeing Airplane Company has developed three different systems or modes of operation to take care of this problem. Without going into the details of these systems, flight tests have shown that, while each of the three modes of operation is best suited to certain classes of aircraft, depending on their relative weight and conditions of atmospheric disturbance, not one of the three systems completely eliminates all of the difficulties. Some of these difficulties are inherent in any flight-refueling system that has a varying length of fuel run.

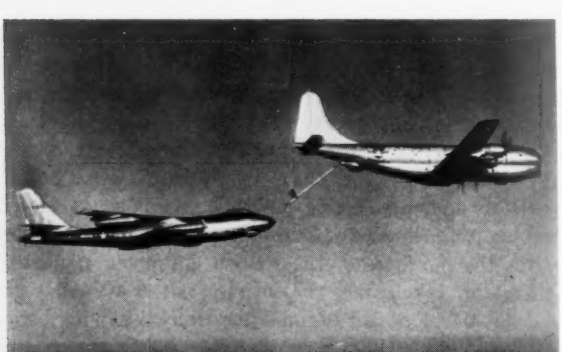

FIG. 4. Boeing B-47 Stratojet bomber demonstrating the flying boom system. The B-47 is being refueled by a Boeing Stratofreighter.

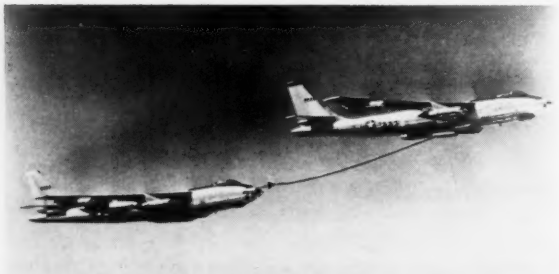

FIG. 5. Illustration of the probe and drogue system.

With the flying boom there are two adverse effects of this problem: one is on the fuel system itself, another is on the flying quality of the combination. Taking the first, it is seen that, because of the fact that the boom must telescope in and out to accommodate for the relative motion of the airplanes while in contact with each other, a series of pressure pulsations is set up within the fuel system as the boom lengthens and shortens. These fluctuations in pressure can have a serious effect on the entire fuel system and must be damped out. The job of damping is accomplished by means of a so-called "boot" incorporated within the boom itself. This pressure-damping boot, although designed to overcome this difficult problem in the boom system, is practically mandatory in any flight-refueling system in order to relieve the surge of pressure which occurs any time an inadvertent disconnect takes place due to some abrupt airplane maneuver. It performs this function in the boom system as well. The second effect of the fuel pressure on the relative rigidity of the boom is on the flight characteristics of the coupled airplane combination. Let us examine the combination when it enters a slight gust. The effect of the gust is first felt by the leading airplane, the tanker, and in the next split second by the receiver aircraft. Both airplanes will start to deviate from their path, first one, then the other, because of the effect of the gust. However, since the leading airplane moves first, it creates a demand for motion in the telescoping section of the boom. This demand is partially resisted by the column of fuel so that a mechanical

couple is produced on the leading airplane, tending to nose it up or down, depending on the direction of the gust encountered. This deviation from the flight path is corrected by the pilot. However, the second aircraft also responds to the gust, and this is counteracted by the pilot in the receiver aircraft. It can be seen that the problem of holding formation no longer evolves solely upon the relative position of the two airplanes to each other but also depends on the magnitude of the force couple produced by the length of the boom between the two aircraft. If a gust occurs while the airplanes are flying with the boom relatively close to its fully extended limit and the couple develops in such a manner as to further separate the two airplanes, an inadvertent disconnect occurs, the fuel flow is shut off automatically, and it is only necessary to recouple in order to continue the operation. On the other hand, if a gust is encountered when the airplanes are flying with the boom near the closed position and a couple is produced tending to force the airplanes closer to each other, the danger must be immediately recognized by the boom operator and the receiver pilot, since it is readily apparent that if the boom bottoms a rigid link exists between the two airplanes which will further aggravate the couple, forcing them together. Once this condition occurs, a resultant action develops very quickly, causing either a structural failure in the boom or boom attachments or an actual collision between the two aircraft. By intensive training of both pilots and boom operators, by picking select crews, and by establishment of rigid emergency break-away procedures, the number of such incidents is relatively rare. No actual collision has ever occurred. Whenever possible, ex-pilots are picked as boom operators. The system is further protected by a complex series of limit switches that energize an automatic disconnect and boom retraction whenever mechanical or fuel pressure limits are exceeded. In turbulent air, the frequency of inadvertent disconnects increases. While this usually results in nothing more serious than aggravation on the part of the refueling crews, it definitely does reduce the average rate of fuel transfer. Thus it is seen that a flight refueling system is far more than a fuel system. What may be optimum from a fuel system standpoint may fall far short of an optimum flight-refueling system because of the other factors that must be considered in making and holding contact between the tanker and receiver aircraft.

In August, 1949, on its own resources, Flight Refuelling, Ltd., demonstrated the probe and drogue system by setting a world endurance record for jet aircraft by refueling a Meteor ten times in flight for a total endurance of some 11 hours. The USAF let a development contract that same year. Fig. 5 shows the elements of the probe and drogue system. A conical drogue is trailed on the end of a length of refueling hose. The drag of the hose and drogue is almost balanced by a drive mechanism on the reel, which continually tends to wind in the hose. A probe is rigidly mounted on the receiver aircraft. in order to make contact, the receiver pilot flies the probe into the conical drogue, where automatic coupling and refueling takes place. In order to disengage, the receiver pilot merely slows down his aircraft until the probe pulls out of the drogue coupling. Automatic valves shut off the flow of the fuel. The wind-up mechanism in the reel constantly keeps the hose taut as the relative position of the airplanes changes during the refueling operation.

The simplicity of this system is readily apparent. Its hose trails at an angle of only 10° to 15° to the relative wind, so that it inherently has a higher design airspeed capability than previous systems of flight refueling. No operator is required, and sequencing of the hose-reel mechanism can be done by one of the regular members of the air crew from a remote position without having visible reference to the refueling operation itself. This also permits multipoint tanker configuration, so that more than one aircraft—and, in practice, up to three—can be refueled at one time. Functional tests of this equipment and development to increase the design air speed and the rate of flow of this equipment have been continuing since 1950. Further, the probe and drogue system permits flight-refueling operations during far higher levels of turbulence than the flying boom system.

The equipment was the first flight-refueling system used in combat (in Korea) and was the first to prove the value of in-flight refueling under combat conditions. Recently, the Air Force announced that a B-47 convertible bomber-tanker had been developed using this equipment. This not only marks the first jet tanker developed but also the first USAF capability to convert a bomber into a tanker in the field, depending on the contingencies of the operational situation. This jet convertible bomber-tanker and a B-47 probe receiver are now at the Air Proving Ground at Eglin Field undergoing operational suitability tests. The probe and drogue system is almost unanimously preferred by Air Force pilots who have flown it and has been adopted as standard by the U.S. Navy.

This system also has its disadvantages. First, it is not optimum from a fuel flow standpoint. This is true because the hose is appreciably longer and smaller in diameter than the flying boom. This means that there is greater resistance to fuel flow and that more pumping horsepower is required to achieve the same average rate of flow as the flying boom. In practice, however, the fact that the probe and drogue permit a greater latitude in the required formation position means that it is practically free of the inadvertent disconnects that occur in the boom system. Thus the rate of flow between the two systems, even assuming identical pumping horsepower, approaches the same average value. Perhaps the greatest problem facing the probe and drogue system is the development of a truly satisfactory refueling hose. Despite the fact that some good performance has been achieved, using essentially commercial hoses, the production of a satisfactory hose is essentially still the result of craftsmanship and ex-

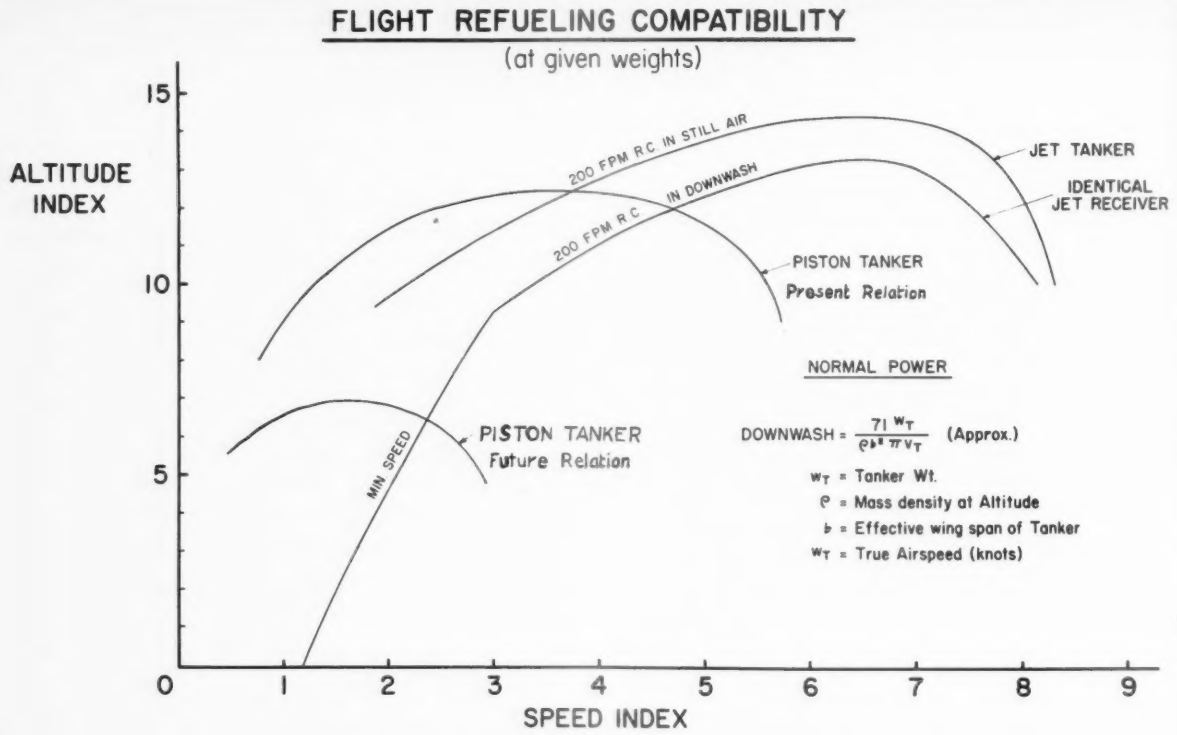

FIG. 6.

tremely rigid methods of inspection and control. Present hoses, produced in this country by the U.S. Rubber Company, consist of a rubber liner reinforced in cross section with a spirally wound wire, the two being integrated by a woven cotton carcass bonded to the rubber liner. For flight-refueling purposes the cotton is the tension member. The reel diameter is a function of the minimum bend radius of this hose. No hose has yet been built which will resist the aromatic content of the fuel and bend satisfactorily at −65°F. Below about −30°F., more and more force is required to bend the hose around the reel. In practice, the reel may be contained within a shroud so that warm air may be circulated around the layers of hose while in flight. The fuel itself also acts to prevent the hose from stiffening to the degree that an unsatisfactory contact would result. This latter statement requires further explanation. In the probe and drogue type system, it is essential that the hose be maintained taut, and this is most critical at the instant that the receiver airplane makes contact with the drogue. If any slack develops in the hose, it may start to whip because of its resilience and the changing air loads resulting from its deflection. This causes extremely high stresses in the hose, shortens the life of the hose, and may actually cause hose failure. In order to ensure that the hose remains taut during the contact, the hose reel must have a high rotational acceleration. This acceleration will be reduced when the hose becomes stiff due to low temperature. Contacts have been made successfuly down to −33°F. after a 1-hour cold soak. However, the door is open to anyone who can produce a more satisfactory hose.

Let us investigate the effect of downwash upon the receiver airplane, irrespective of the equipment in use. Fig. 6 shows the effect of downwash from the tanker airplane on the receiver airplane flying a step-down formation behind the tanker. It may be noted that there is a main path of maximum downwash with a decreasing effect above or below this main area and with decreasing effect the farther the receiver airplane flies behind the bomber airplane. Both boom and probe and drogue refueling is done with the receiver in this disadvantageous position. The downwash causes a reduction in the service ceiling between identical airplanes of many thousands of feet. The effect of downwash is even more severe when a relatively slow airplane is used to refuel a jet receiver. The jet airplane is already penalized by being forced to refuel at a speed far below its normal cruising speed, which forces it to fly at a high lift coefficient. In this attitude of flight we say that the receiver is flying on the backside of its power curve. As the refueling proceeds, the receiver becomes heavier and its stalling speed approaches the maximum speed of the tanker. At the same time, power is required to maintain an angle of climb equal and opposite to the downwash from the tanker. At high altitudes and slow speeds, this amount of power is not available. Altitude must be sacrificed to reduce both the high lift coefficient of the receiver and the angle of downwash from the tanker until enough power margin is available to maintain position.

From a design point of view, it would appear imperative that the receiver airplane be moved out to the side of the tanker airplane so that it would not be flying in the downwash of the tanker airplane. In actual practice, the Air Force has been conducting an operational service test wherein the tip tanks of fighter aircraft are equipped with a probe, and one of the B-29 tankers incorporates a multipoint refueling system with hose-reel units mounted both in the fuselage and on each wing tip. It can readily be seen that with this combination the fighters can make contact when flying outside of the downwash of the bomber. A notable increase in operational altitude has been reported when the receiver makes contact from this position as compared with the step-down position behind the tanker. Unfortunately, the practical use of this feature is limited to relatively small fighter aircraft and particularly to those having straight rather than swept wings. It would be desirable if a B-47 or a B-52 airplane could be refueled with a wing-tip-mounted probe in contact with a wing-tip-mounted tanker hose-reel assembly. Unfortunately, with these airplanes, the wing tip is located so far behind the pilot, and so far distant from the pilot, that a practical refueling system based on this configuration does not appear to be within the realm of feasibility due to the lack of adequate vision for the receiver pilot.

Turning from equipment development, what are some of the operational considerations? What kind of an airplane shall be used for a tanker? Fig. 7 shows two graphs, located physically one above the other. Examining the lower graph, which shall represent the receiver airplane it is seen that it is essentially an economy graph—pounds of fuel versus radius of action. The maximum weight is the take-off weight; the minimum weight is the landing weight. By expending this weight of fuel the airplane is capable of proceeding out to the stated radius of action and returning to home base. Reserve fuel is not considered in this particular problem. Above this graph is represented another airplane of identical size and identical economy, which shall be the tanker. If these two airplanes are identical, they have the same radius of action. The graphs shown assume that fuel consumption is a straight-line variation with distance. While this is not actually true, it makes little difference for purposes of illustration. Proceeding from take-off, a point is reached where one-third the total weight of fuel has been expended in both airplanes. At this point the tanker may transfer one-third of its fuel to the receiver and proceed home. With this amount of fuel, the receiver may exceed its previous radius of action by one-third. Thus, if the airplanes are identical, only a one-third increase in radius of action is gained by a flight-refueling operation where both airplanes are taking off and landing from the same base. It follows that any other tanker of smaller size having the same economy as the receiver airplane can transfer less fuel, and this therefore adds less range to the receiver. If the tanker is too small, it is hardly worth using. If a receiver is too small, it will require a disproportionately large tanker to transfer the required amount of fuel to make good a maximum radius mission. If tanker and receiver are identical in size an inbound and outbound refueling will give a two-thirds range increase. It is axiomatic that, the shorter the range the tanker is required to fly, the more fuel it will have available for transfer to the bomber. Therefore, a double-refueling outbound will not give so great a range increase as the outbound-inbound scheme. Further, it can be shown that the same tanker can make both the outbound and inbound contacts with time to spare. Although inbound refueling has been conducted, its use presents a great risk, since the receiver will not be able to return to a friendly base if its equipment has received battle damage.

From a dollars and cents point of view, the thought of using a tanker the same size as a bomber is still abhorrent to some people. Examine Fig. 8, which is generally known as the weight-range asymptote of an airplane. A simple graph is shown which indicates how the design weight of an airplane increases with an increase in design range. Pick a point at which the range and the weight are very great indeed. It is obvious that, if an airplane is selected of half this weight, it has a shorter range than the larger one. However, it can

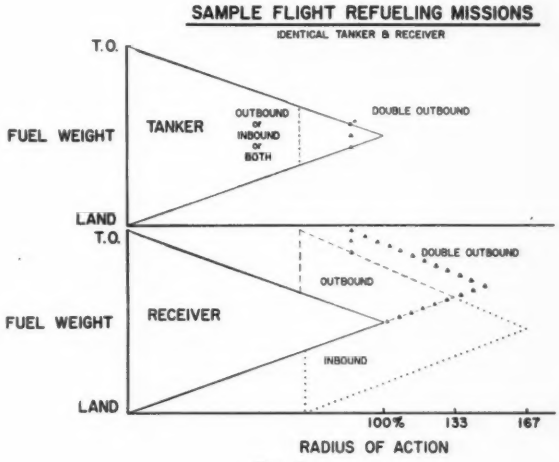

FIG. 7.

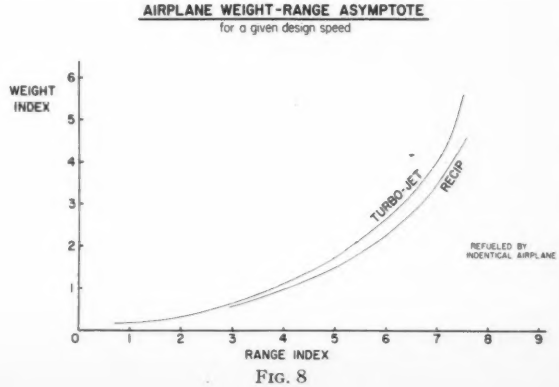

FIG. 8

also be seen that a one-third range increase by flight refueling would give this smaller plane a range as large as, or larger than, the extremely heavy weight airplane first selected. It happens that the airplane first selected falls in the category of the airplanes that are required today to accomplish a truly intercontinental mission. It follows then that airplanes of half this weight can be built to accomplish the same mission as the large airplane if one refuels the other in flight. In considering attrition over the target, it should be lower than the large airplane because it presents a smaller target. In considering national resources, the small airplane is better, since only one-half the man-power investment is lost if the enemy's interception is successful. This figure, then, presents the basis of the argument that flight refueling is economical.

If the two airplanes are identical, certain operational and logistical advantages will accrue which further the economical aspects of the plan. Assuming that the airplanes can be converted to tankers at will, a case the Air Force is now investigating in the B-47, the operation of the airplanes as either tankers or bombers can remain within the control of the same unit organization, a squadron. The squadron commander can decide when to convert part of his force to tankers, depending on the mission he is ordered to fly. Therefore no complex interorganizational planning is required. The entire success of the attack becomes a function of the unit commander. This relates also to a principle of warfare, known as the "unity of command," and is one of the prime essentials in organizing a successful attack. If the planes are identical, they can take off from the same fields and fly in the same formations, and the pilots can take turns being the tanker or receiver pilot. This builds esprit de corps. A system of operation where some men only fly the tankers and others the bombers does not build the same spirit. It is self-explanatory that, where identical airplanes are used for both tanker and receiver, the problem of logistics is halved.

FIG. 9.

Nonetheless, there are many practical considerations in choosing the tanker airplane. The world-wide nature of the Air Force's strategic mission assesses great importance to the role of a supporting cargo fleet. Assuming a condition where both the bomber and the supporting cargo fleet must deploy to an advanced operational base, it is possible to utilize this same supporting cargo fleet as tankers in support of the bombing mission. This is the concept leading to the development of the KC-97 cargo tanker. Despite its practical nature, the plan has obvious shortcomings. Cargo planes no longer have speeds even nearly comparable to that of the first-line bombardment airplanes. Fig. 6 showed that this produces a narrow compatibility range where the refueling operation may successfully take place. The altitude at which refueling may take place is also lowered. This introduces elements of descent, high fuel consumption during the refueling operation, and climb-back to altitude for the jet bomber. The airplanes respond to gusts differently. Worse still, there are certain compromises to the function of the airplane. The cargo airplane must use a portion of its flight hauling cubage in order to provide fuel stowage in sufficient quantity to meet the demands of the bomber airplane. It introduces an element of rendezvous into the refueling operations, since the slower tanker must take off many hours ahead of the bomber flight in order to rendezvous at the same time. The rendezvous itself is not considered serious, but delays and confusion due to airplane aborts are considered serious. The tanker flight also becomes extremely vulnerable to attack unless the operation is conducted well outside the enemy combat radius of action.

Air Force policy to date has limited the use of first-line bombardment aircraft as tankers. Recognizing the inadequacy in certain respects of a cargo tanker fleet, a third solution has been used to considerable extent. Second-line bombardment aircraft are relegated to a supporting role as tankers. In this category is found the KB-29M looped-hose and KB-29P flying boom tanker airplanes.

The case for refueling tactical aircraft is a lengthy one. Suffice it to say that refueling may be used to increase the radius of action, to increase the bomb load, to increase the hover or patrol time in the target area, to provide a rescue service in case the home base closes in due to weather, and to increase the ferry range of the fighter. With long-range fighters, one fighter may be used to refuel the other. The Tactical Air Force has

supporting cargo airplanes that may be used as tanker aircraft. However, such use must be specially defined, as the fighter normally operates over the enemy front lines, eliminating any possibility of using a cargo plane as a tanker. Second-line bombardment aircraft may also be used as tankers in support of tactical aviation.

Fig. 9 presents what are believed to be the elements that must be considered in order to provide the necessary features for a successful flight-refueling system. It is hoped that this paper will have served to substantiate the relative importance of the design elements indicated.

The equipment may be simple; its scope remains complex. One thing is certain: flight refueling is no longer a stunt. Flight refueling has arrived. The Air Force has made over 120,000 refueling contacts. It is currently averaging over 7,500 contacts and transferring 1,200,000 gal. of fuel per month. It appears that flight refueling shall remain a prominent part of the weapon systems business as long as conventional fuels are used to power the aircraft.

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Turboprop Engines for Tomorrow's Transport

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Wright Aeronautical Division, Curtiss-Wright Corporation

Introduction

Several turboprop power plants have already been installed in commercial aircraft, notably the Allison T-38 in the Turbo-Liner, the Rolls-Royce Dart in the Vickers Viscount, and the Bistol Proteus in the Brittania. The Viscount was placed in air-line service in 1952, while the Brittania is expected to go into service in 1954 or 1955. These airplanes have been progessing nicely in relative obscurity compared with the tremendous fanfare given to the De Haviland Comet as the future transatlantic jet transport. It is perhaps significant that, despite all the publicity for the Comet, foreign air lines have placed larger future orders for both the Brittania and the Viscount than they have for the Comet.

In contrast to this optimism of the British with regard to the future of the turboprop is the conservative approach taken by the American aviation industry. The general sentiment here seems to be that, while the Turboprop is potentially desirable, there are a great many practical difficulties to be overcome before it can be applied to civil aviation. Despite this general reluctance, however, there are several more advanced turboprop installations underway, such as the turboprop-powered Douglas C-124, the Lockheed C-130A, and Lockheed R7V-2. These models can be used to evaluate and iron out the operational problems that are introduced with the turboprop power plant.

The problem of selecting the power plant for the commercial transport of tomorrow is one that has received a great deal of attention over the past 7 years. The question has been complicated by the variety of power plants to be considered, such as the turbojet, the turboprop, and the compounded reciprocating engine. Each power plant poses its own particular set of problems which must be evaluated fairly in relation to those of the competing types of power plant.

The relative performance of each type of power plant has been thoroughly analyzed in many previous papers. There is broad agreement among all the authors as to the portions of the flight spectrum where each type excells in performance. The turbo-compound reciprocating engine has demonstrated speeds of 400 m.p.h. at altitudes above 20,000 ft. and is recognized as having additional growth potential.

Presented at the IAS New York Section Meeting, Swiss Chalet, Rochelle Park, N.J., October 22, 1953.

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‡ Project Engineer, Turboprop Engine Development.

The turboprop prefers a speed range of from 400 to 500 knots and provides good performance up to the sonic range and at altitudes from 20,000 to 40,000 ft. The preferred range of the turbojet is at flight speeds in excess of 500 knots.

The differences of opinion that do exist as to the relative merits of these power plants are with regard to the operational advantages of each type, to the probable state of development of each power plant at any future date, and to the importance of the development difficulties to be overcome on each type. Further differences are introduced when an attempt is made to evaluate the price differential that a passenger would be willing to pay for a faster trip. This factor is at the heart of the question as to whether tomorrow's transport should cruise at 400 knots or at 500 knots.

The resolution of these questions will require an extensive, thorough, and impartial review of all contributing factors, which include performance, operation, maintenance, reliability, air-line economics, passenger comfort, and safety.

Such a comprehensive review of this question is certainly beyond the talents of the present authors, who wish to restrict their remarks to the current status of the turboprop engine, its advantages, and certain problems that must be resolved in order to place it in a competitive position for powering tomorrow's transport.

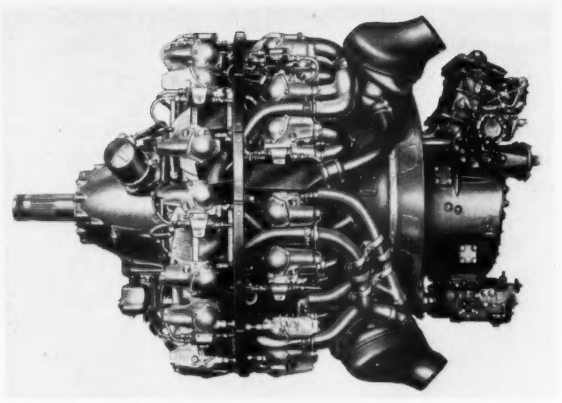
Advantages of the Turboprop

The following is a brief résumé of the chief advantages of the turboprop engine, which have been discussed in detail by numerous authors during the past decade. It is not all inclusive but does list those items upon which there is apparent agreement by members of industry who have reported their thoughts on the subject.

Turboprop vs. Compounded Reciprocating Engine

(1) The turboprop engine raises the power per engine limit from the present-day 3,000–4,000 s.hp. to possibly 15,000 s.hp., thus making possible increases in aircraft size and speed without increasing the number of nacelles beyond the optimum.

(2) The turboprop engine has considerably less frontal area and weight per equivalent shaft horsepower, and it achieves maximum efficiency at a higher per cent of take-off power, permitting optimum operation at higher altitudes. This, coupled with the use of cheaper fuel, results in reduced fuel costs at speeds above approximately 400 knots.



Wright turbo-compound powers today's transports

(3) The reduced noise and vibration level of the turboprop results in greater comfort to the passengers and crew and less maintenance to the aircraft.

(4) Turboprop engines of the future will probably be designed to operate on low-viscosity oils and will contain an integral oil system that eliminates the need for oil dilution and complex cold-weather starting procedures and also reduces the requirements for air to oil coolers and the attendant drag losses.

(5) Compressed air will be avilable from the engines for cabin pressurization and aircraft deicing and as a power source for driving auxiliary equipment.

(6) Improvements in design now under development (increased pressure ratio, increased turbine inlet temperatures, and transonic and supersonic propellers) will accrue additional advantages to the turboprop, particularly with regard to fuel consumption and increased range and speed.

Turboprop vs. Turbojet

(1) The higher propulsion efficiency during take-off and the use of the propeller for braking during landing permit safe operation of the turboprop off shorter length runways. The reversible propeller also makes possible aborted take-offs and landings on icy runways as an added safety feature.

(2) The fuel consumption of the turboprop is considerably less than that of the turbojet at speeds up to 500 knots. This economy is available at lower altitudes for the turboprop which reduces the development problems involved in flying transports at 40,000 ft. and above. With transonic and supersonic propellers, it appears possible to extend this speed even beyond that considered feasible for the transports of the immediate future.

(3) Because of its lower fuel consumption, the range of the turboprop-powered transport of a specified gross weight will be nearly twice that of the turbojet-powered transport of similar weight.

(4) The noise level of the turboprop is less than that of the turbojet because of the lower velocity at which gases leave the jet nozzle. Although the noise and vibration due to the propellers have not proved to be objectionable to passengers to date, the effect of high-speed propellers has not been thoroughly evaluated.

(5) Future improvements, such as increased pressure ratio and increased turbine inlet temperatures, will result in even greater improvement to the performance of the turboprop engines than to that of the turbojet.

Current Status of the Turboprop Power Plant

At the present time, development is in progress on turboprop power plants in all power classes ranging from 200 to 10,000 s.hp. Of the domestic power plants, the Allison T-38 and T-40 and the Pratt & Whitney T-34 are perhaps the most widely known. The Allison engines have been installed in the Convair P5Y and the Turbo-Liner, and these installations have been thoroughly detailed in several papers. The Pratt & Whitney T-34 was released within the past year for commercial use. Likewise, the Curtiss-Wright Corporation is actively developing turboprop engines; however, security regulations restrict discussion to the statement that these engines are in a power class greater than any other turboprops now known to be under development. Another significant point is that the basic gas generator for these power plants is a highly developed unit.

Fig. 1 shows several of the current British and American turboprops for which data have been published. The fuel consumption of the Proteus at 0.51 approaches the fuel consumption of a normal uncompounded reciprocating engine. This is doubly significant, since the pressure ratio of the Proteus is fairly moderate. Several engines well advanced in development in this country are capable of substantially lower fuel consumption than the Proteus. Furthermore, other high pressure ratio engines now going into development will have lower fuel consumption than currently obtainable on the compounded reciprocating engine.

The Turboprop Basic Engine

To convert a turbojet engine to a turboprop engine basically requires modification to the gas turbine to

CURRENT TURBO PROP ENGINES

MANUFACTURER	NAME/MODEL	ESHP	WT. ESHP	WF. ESHP(S.L.)	WF. ESHP(ALT)
AMERICAN					
ALLISON	T38	2750	.45	.63	--
ALLISON	T40	5500	.45	.63	--
ALLISON	T56	3750	--	--	--
PRATT & WHITNEY	T34	5500	.48	.61	--
CURTISS WRIGHT	--	--	--	--	--
BRITISH					
ASM	MAMBA 2	1480	.52	.73	*.67
	DOUBLE MAMBA 1	2965	.575	.73	*.67
	PYTHON 1	4550	.76	.77	*.80
BRISTOL	PROTEUS 2	3510	.83	.89	**.51
	COUPLED PROTEUS 2	7020	1.02	.89	**.51
ROLLS ROYCE	DART 504	1515	.60	.83	--

*350 MPH 20,000 FT. ALTITUDE
**350 MPH 35,000 FT. ALTITUDE

Fig. 1.

REQUIREMENTS OF A GOOD TURBO PROP CONTROL

1. OPERATION AT ALL POWER CONDITIONS AT GOOD EFFICIENCY.
2. SIMPLE, RUGGED, RELIABLE AND SERVICABLE.
3. PROTECT ENGINE AND PROPELLER FROM DANGEROUS OPERATION.
4. SATISFACTORY RATE OF ACCELERATION.
5. SMOOTH MODULATION OF THRUST WITH PILOTS LEVER.
6. SLIGHTLY NEGATIVE THRUST AT FLIGHT IDLE DURING LANDING APPROACH.
7. CONTROLLABLE REVERSE THRUST FOR ABORTED TAKE OFF AND BRAKING AFTER LANDING.
8. PREVENT EXCESSIVE NEGATIVE THRUST AS A RESULT OF ENGINE FAILURE.

FIG. 2.

extract the additional energy from the gas stream and the incorporation of a reduction gear to transmit this energy to the propeller. The turboprop turbine, while differing from the turbojet turbine in number of stages and in load distribution, is based on the same design principles and practices. Its development has been found to be equally straightforward. The development of a reduction gear of high step-down ratio capable of delivering large horsepower outputs likewise has not been found to be difficult for the engine companies who have had previous reduction gear experience.

The conversion of a turbojet gas generator to a turboprop does involve some other secondary problems that require attention. Most new turboprop engines have close-coupled reduction gears with annular air intakes around the reduction gear housing. Careful consideration must be given to anti-icing in this air passage ahead of the compressor intake. Another problem to be considered is the mounting problem, where the loads in the turboprop installation are much greater than in the turbojet.

The conversion of a turbojet gas generator to a turboprop, therefore, is relatively straightforward and fairly free from unexpected difficulties. It is worthy of note that such a conversion will, in general, provide almost three times as much take-off thrust at sea level and approximately one-third less fuel consumption at 30,000 ft. up to speeds of 435 knots than the parent turbojet engine.

Turboprop Engine Development

One of the important barriers to more rapid progress of the turboprop, particularly here in America, has been the lack of sustained development effort compared with that expended on turbojets. Most of our power-plant developments in this country have been supported primarily by the military. Most military aircraft place a heavy premium on speed, often to the exclusion of other factors. It is, therefore, natural that the development of turbojet types would receive much greater priority than turboprop power plants. This fact is often used as a basis for the belief that the turbojet would always be in a more advanced state of development and, hence, would be more efficient than the turboprop.

This contention is most valid at the present time when both types are more or less in their infancy and where the disproportionate results of this practice are large. However, the differences in turbojet and turboprop engines are not great, consisting mainly in the development of reduction gears and controls for the turboprop engines. Most of the advances in the turbojet engine are therefore being incorporated in the turboprop power plants almost simultaneously, and the component performance of both types will become more nearly alike in the future. Furthermore, future developments in the fields of high pressure ratios and high combustion temperatures result in greater performance improvements to the turboprop than they do to the turbojet.

Nevertheless, if the turboprop is to fulfill its potential, a more sustained development effort must be provided. There are development problems peculiar to this type of power plant that can only be overcome by flight and service testing.

The Turboprop Control

Requirements of the Control

If a turbojet can be converted so simply into a turboprop with such excellent results, why then do we not have more advanced turboprops flying at the present time? The answer lies in the control problems and certain operational problems that are introduced with the turboprop power plant. The addition of a variable-pitch propeller to the basic jet results in another degree of freedom. It is natural that the problems of control should be somewhat more complex. The turboprop control problems have been serious and often perplexing, and where they have not been appreciated, they have on occasion led to disaster. The nature of these difficulties, however, is no mystery and, like any other engineering problem, yields to analysis and development.

Before we attempt to consider these particular difficulties it may be desirable to outline what we should expect of a good turboprop control system. (See Fig. 2.) First of all, we would like to have this system provide for operation at all power conditions from minimum to maximum as near to the optimum overall efficiency points as possible. Second, we should prefer our control system to be simple, rugged, reliable, and serviceable. But, most important of all, we must insist that, under any and all flight conditions, it protect the airplane and the engine-propeller combination from any dangerous operation.

Some of the operating regions that are dangerous to the engine are those where overspeed, overtemperature, or compressor surge can be encountered. Adequate protection against these conditions must be provided in the control for both steady-state and transient conditions. The transient or accelerating schedule, however, must not unduly compromise the rate of acceleration. Another protective feature to be built into the control system is a propeller shaft torque limiter. Most

turboprop power plants have their reduction gears sized for nearly standard day performance and, hence, cannot absorb the maximum power that the gas generator can deliver on a cold day.

With regard to the airplane, it is essential that at all times the thrust output of the propeller-engine combination be stable and capable of rapid and smooth modulation with the pilot's lever. Discontinuities and dead bands in thrust in response to motion of this lever can lead to confusion on the pilot's part and subsequent loss of control of the airplane. It is also desirable that the thrust developed with the lever in the flight idle position be slightly negative to permit a satisfactory approach to the field. Since the basic gas generator output is noticeably sensitive to changes in ambient air temperature and air bleed for anti-icing cabin pressurization, etc., it is essential that this flight idle thrust setting be maintained fairly constant despite changes in ambient air temperatures and bleed air requirements. It was mentioned previously that the acceleration characteristics of the engine must not be compromised. Rapid restoration of thrust on a landing go-around requires almost instantaneous acceleration from flight idle to military speed and power. Another consideration for aircraft safety is the need for controllable reverse thrust to abort a take-off when required and to land on icy runways.

The requirements for simplicity, ruggedness, and reliability also cannot be overemphasized. The safe and controllable operation of the turboprop engine demands complete reliability of the control components.

Description of the Control

While many different approaches can be taken to obtain the control objectives described above, experience and development have narrowed down the methods considerably. The system that will be described herein is one that with variations is now being applied to most of the active turboprop projects and is therefore the method that will receive the greatest developmental effort in the next few years.

In this system two different régimes of operation are provided—one for all flight conditions and the other for ground handling. (See Fig. 3.) For both régimes, the propeller and fuel controls are coordinated through a single power lever. In the flight régime, engine r.p.m. is governed by changes to propeller blade angle, and the power setting is established by the fuel control, generally at a point close to the optimum efficiency setting. While several types of fuel control are in use, the most useful appears to be those that determine the engine airflow by measuring inlet air temperature, compressor r.p.m., and compressor discharge pressure. Having determined airflow, the control meters the fuel to arrive at a prescheduled turbine inlet temperature. Such a control incidentally can maintain fairly uniform turbine inlet temperature with varying quantities of compressor air bleed. This control must also incorporate a suitable acceleration schedule to provide maximum acceleration while protecting against surge and transient overtemperature. In addition, the fuel control must have overspeed protection in case of a propeller governing failure, as well as the ability to reduce fuel flow when the engine torque exceeds permissible limits.

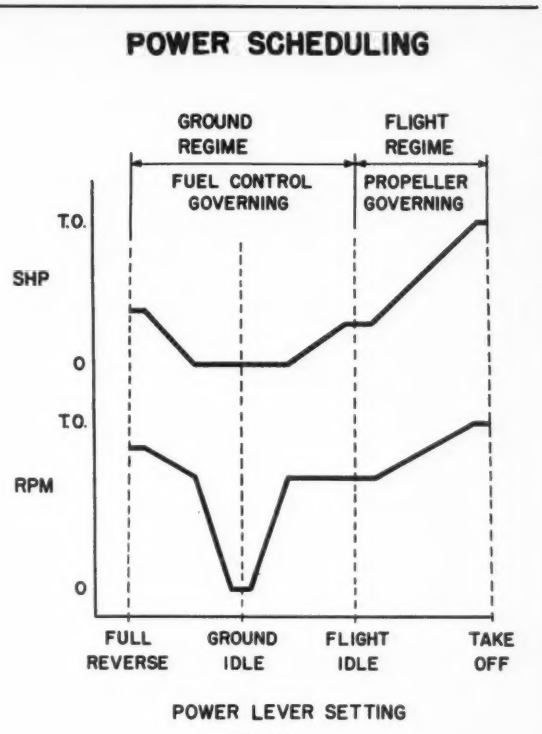


FIG. 3.

For ground handling, where both positive and negative blade angles are required, it is no longer practical to govern with the propeller. For this régime, therefore, the propeller blade angle is positioned as a function of the pilots lever, while the fuel flow governs to the scheduled r.p.m. This permits the scheduling of positive thrust as required for taxiing and reverse thrust for braking the aircraft after landing.

To prevent operation in the ground régime portion of the pilot's lever when in flight, a suitable lockout gate is required. Furthermore, the blade angle scheduled in the ground-handling régime at the gate must be the same as the governing blade angle at touch-down speed. If this precaution is not taken, thrust discontinuities can be produced when going from one régime to the other.

The Approach Condition

Since it is expected that tomorrow's transport will be designed to operate at much higher flight speeds than those of today and will therefore have a much flatter glide angle in its approach to the field, it becomes doubly important for the control to provide characteristics acceptable during this approach condition. Basically, the aircraft will need a slight negative thrust during these conditions in order to increase the angle of glide and permit approach over high obstacles, as well as enable the pilot to better target the landing at the

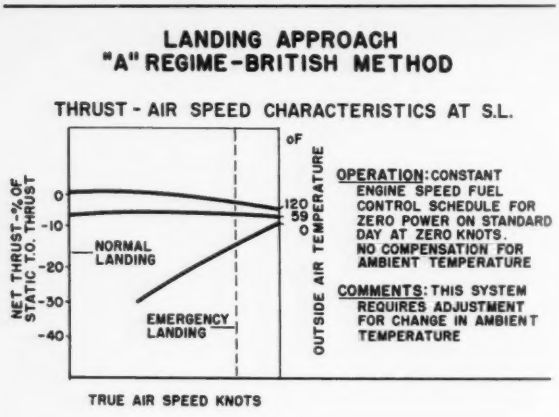


FIG. 4.

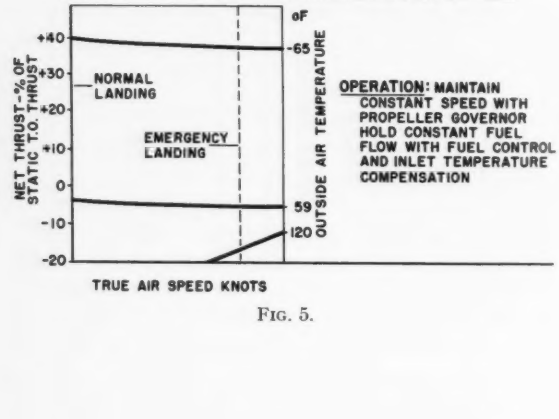


FIG. 5.

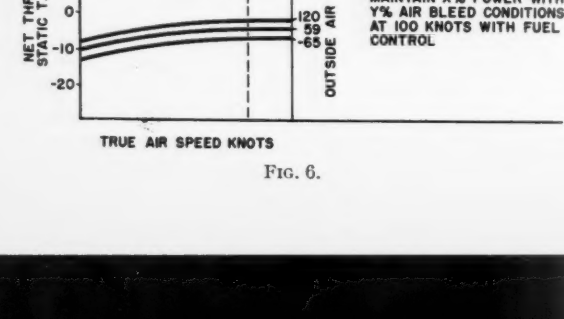

LANDING APPROACH
"C" REGIME-CONSTANT ENGINE SPEED X% POWER WITH Y% AIR BLEED AT 100 KNOTS
THRUST - AIR SPEED CHARACTERISTICS AT S.L.
NET THRUST-% OF STATIC T.O. THRUST
0
-10
-20
NORMAL LANDING
EMERGENCY LANDING
°F
120
59
-65
OUTSIDE AIR TEMPERATURE
OPERATION: MAINTAIN CONSTANT SPEED WITH PROPELLER GOVERNOR. MAINTAIN X% POWER WITH Y% AIR BLEED CONDITIONS AT 100 KNOTS WITH FUEL CONTROL
TRUE AIR SPEED KNOTS

FIG. 6.

beginning of the runway, thus minimizing the danger of overshoot and subsequent go-around. It is also desirable that the thrust produced by the engine-propeller combination during the approach condition be consistently repeatable regardless of variation in ambient air temperature and per cent bleed from the compressor. Another requirement in the case of multi-engined aircraft will be that the thrust from each nacelle be equal or nearly equal to minimize the asymmetrical thrust problem. The most important requirement, however, is that the control provide stability with no oscillations in power and thrust. Failure to appreciate this last requirement has in the past led to serious problems during the landing of certain aircraft.

The problem of supplying negative thrust during the approach condition is fairly straightforward. Basically, it is a matter of scheduling a certain engine speed and blade angle so that during the approach condition the propeller absorbs power from the air rather than absorbing power from the engine. Under these conditions the net thrust experienced by the aircraft will be the difference between the negative thrust from the propeller and the slightly positive thrust from the jet. This method is straightforward and is utilized by turboprops flying today. Where provision has been made in the engine for decoupling or for control feathering to eliminate the negative thrust problem (discussed in greater detail later), some difficulty may be experienced in providing the optimum amount of negative thrust during this approach condition. This problem is solved by biasing the action of the decoupler or negative thrust device so as to operate at a small value of negative torque (for example 5 or 10 per cent instead of zero torque).

The problem of asymmetrical thrust is due to the fact that one engine produces more or less thrust than an engine in another nacelle. This condition results from the accumulation of tolerances in the control cable linkages and in the fuel controls and propeller controls themselves. The best that can be done is to recognize this problem before designing the components and to make a special effort to minimize the tolerances at this particular condition of operation. Small values of asymmetry are not expected to be objectionable and can be almost entirely eliminated by the pilot in his approach pattern by adjusting power lever positions.

We now come to the important requirement of having to supply a consistently repeatable thrust regardless of variation in ambient air temperature and per cent air bleed. The most satisfactory solution of the problem would be for the control to schedule a constant engine speed and a constant propeller shaft torque. Under this condition the operation would be to hold constant speed with the propeller governor, to set torque on one engine, and for the other engines to be automatically equalized by adjusting fuel flow. This system would require a torquemeter signal to influence fuel flow and for this reason is not recognized as a satisfactory solution to the problem. It involves an extremely accurate,

highly responsive, and fully reliable torquemeter, as well as a more complex control system.

There are three solutions to the problem now in use both here in America and in Great Britian. Régime A (Fig. 4) is one being used by British engine manufacturers. It operates on the principle that the propeller governor schedules a constant engine speed and that the fuel control schedules fuel to the engine which will give zero power on a standard day at zero knots. This system has no compensation for ambient temperature and requires fuel control adjustment for changes in these values. It can be seen that with a temperature change from 59° to 120° this system results in a slightly positive thrust that is not satisfactory. A reduction in ambient temperature to zero degrees results in large values of negative thrust which increase with reduction in speed requiring jockeying of the power lever during landing. This is both undesirable and dangerous.

Another solution is shown as Régime B (Fig. 5) in which case a propeller governor schedules a constant engine speed and the fuel control schedules a fuel flow that compensates for variations in inlet air temperature. This method, in effect, maintains constant burner temperature and results in extremely large variations in thrust with ambient temperature. This system would result in serious operational problems in a transport scheduled to fly between airports subject to large variations in ambient air temperature.

A third solution to this problem is presented as Régime C (Fig. 6). In this solution the propeller governor schedules and maintains a constant engine speed, and the fuel control schedules the necessary fuel to maintain a desired per cent of power with a certain air bleed condition at the expected touchdown speed of the aircraft. As can be seen from the figure, the thrust variation from minus 65° to plus 120° is relatively small at all approach air speeds. This can be accomplished without undue complication to the control system and can be made to provide perfectly stable operation of the engine.

The Landing Condition

Under normal landing conditions it is desirable to reduce the speed of aircraft to that required for taxiing in as short a time as possible commensurate with passenger comfort and structural safety. In the turboprop-powered aircraft this can be accomplished successfully with a reversible-pitch propeller to supply high values of negative thrust after touchdown.

As desirable as this feature is in normal landings, it becomes an essential safety feature during the following abnormal landing operations:

(1) Overshoot on a short runway.

(2) Landing on an icy runway.

(3) Landing with jammed or inoperative flap control system.

With regard to this last situation, it is interesting to compare the thrust characteristics of a turbojet-powered aircraft of today with that of a turboprop incorporating

NEGATIVE THRUST AVAILABLE AT TOUCHDOWN WITH REVERSABLE PROPELLER

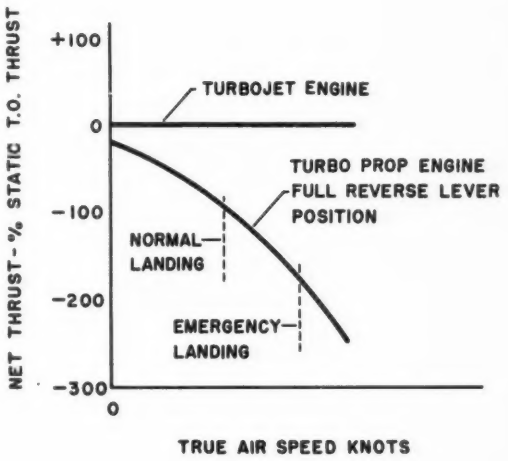


FIG. 7.

a reversible propeller. From Fig. 7 it can be seen that in the emergency landing condition the jet engine will supply from 5 to 10 per cent positive thrust, whereas the turboprop can develop negative thrust equal to 150 to 200 per cent of its static take-off thrust.

It is recognized that the above comparison will not hold true for tomorrow's jet-powered commercial transport. The importance of increased safety under the landing conditions described above is paramount, and it is considered unlikely that a transport will be acceptable for large-scale commercial use unless some provisions are made for reverse thrust. In the case of the turboprop engine, the reverse thrust provisions have been inherited from reciprocating engine practice and are considered to be reliable and well developed. In the case of the turbojet, the devices that have been proposed have yet to be proved acceptable as a design and are confronted with an extended development program.

NEGATIVE THRUST PROBLEM

Another problem that has been found to be extremely serious in controlling the turboprop-powered aircraft is one that occurs when there is a sudden burner blowout or a structural turbine failure resulting in the complete inability of the turbine wheel to extract power from the gas stream. When this occurs on an engine equipped with the control that has been recommended above, the immediate result is for the compressor and propeller combination to reduce speed. (See Fig. 8.) The propeller, however, senses this, and the propeller governor calls for a reduced blade angle in an effort to maintain the speed scheduled by the throttle lever position. This

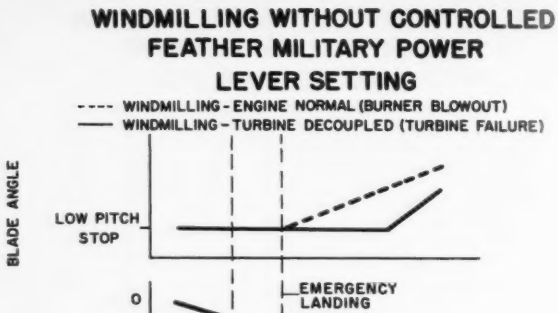


FIG. 8.

reduction in blade angle will continue until a stable speed is achieved or until the low pitch stop is reached. This can result in a high negative thrust being imposed on the aircraft. This negative thrust is a result of the parasitic drag of the low pitched propeller and the power that it extracts from the air stream in order to drive the compressor. The value of the negative thrust developed under certain flight conditions can be extremely high, imposing dangerous structural loads and/or completely upsetting the control of the aircraft. This is what is frequently referred to as the negative thrust problem.

The seriousness of this problem insofar as the safety of a particular aircraft is concerned depends, of course, upon the value of the negative thrust developed and the attitude of the plane at the time of failure. From the standpoint of aircraft attitude, there are three conditions of particular interest. They are: during take-off and initial climb, approach and landing, and the stabilized flight condition during which the maximum value of negative thrust can be developed. The first two concern themselves with the conditions under which loss of control would almost certainly result in disaster. The last one is concerned primarily with the structure of the aircraft and the loads that it must be designed to withstand. The value of the negative thrust which will be developed depends upon the forward speed of the aircraft, the rapidity with which pitch change is accomplished, the minimum pitch angle stop setting, the altitude, and the power lever setting. The maximum value will be encountered at a high forward speed and low altitude, with a rapid pitch change mechanism, a low minimum pitch angle stop setting, and a high power lever setting. Under these conditions negative values in excess of twice the take-off static thrust can be developed. Under conditions of take-off or landing where forward speeds are reduced, the values are reduced. However, they are still of sufficient magnitude to cause loss of control of the aircraft. It is well understood by all concerned that this is a serious problem and must be overcome at all costs.

From the above it would appear that possible ways of reducing the seriousness of the problem would center around the rate of pitch change and/or a variable minimum pitch angle stop. With regard to the rate of pitch change it might be argued that, if it were made sufficiently low, the transition from positive thrust to negative thrust might be made to extend over a sufficiently long period of time to allow the pilot to diagnose the problem and to apply corrective action—such as manually feathering the propeller. This is unsatisfactory for several reasons. The two most important are that it imposes an excessive burden on the pilot and that the turboprop engine requires a high rate of pitch change to accommodate other operational and control requirements.

It has also been suggested that the minimum low pitch stop can be made to vary with the flight attitude of the aircraft and the power lever position so as to minimize the value of the negative thrust produced. This has some merit but adds complication to an already difficult control design and development problem. At best it would reduce the value of negative thrust. Inasmuch as reliable solutions are possible which can eliminate the problem, it hardly appears to justify the expense and effort required for its development.

There are three practical solutions to this problem which are being developed at the present time. They are: (1) the free turbine, (2) automatic decoupling, and (3) controlled feathering. In the free turbine solution, the compressor and the propeller are no longer mechanically coupled. The compressor is driven through the outer shaft by one turbine, while the propeller is coupled to the low-pressure turbine by a second concentric shaft. This arrangement minimizes the negative thrust developed and has been successful in the Bristol Proteus engine. There are, however, some additional considerations on the debit side of the ledger. First, it has been reported that this system requires a propeller with an extremely high rate of pitch change to prevent overspeeding when going into reverse pitch for braking. Second, the application of this solution to twin spool high pressure ratio engines results in three concentric shafts with insoluble difficulties with regard to shaft stiffness, bearings, and seals. No twin spool designers are known which have attempted this free turbine solution. For this reason most American engine manufacturers have not favored the free turbine solution.

An alternate solution to this problem can be provided by automatic decoupling. With this method a mechanical device decouples the propeller from the compressor whenever the propeller attempts to drive the compressor. This mechanism must be so constructed that the shafts are automatically re-engaged whenever positive driving torque is restored. For optimum approach characteristics, some steady-state negative torque is desirable. Hence, it is preferable to have the auto-

matic decoupling take place at some nominally small negative torque value rather than at zero torque. The design and development of lightweight, fully automatic decoupling devices is actively under way by several engine manufacturers. These devices, when perfected, would provide a fully reliable mechanical solution to the problem of high negative thrust.

The third method of handling negative thrust is that of controlled feathering. This particular solution is the one that has received the greatest attention to date both here and in England. With this system a device is built into the reduction gear which recognizes when the torque has become negative or when the propeller has begun to drive the compressor. This mechanism produces a motion of a mechanical link which can energize the feathering circuit of the propeller. The feathering circuit is kept energized only so long as the negative torque is present. When the positive driving torque is restored, the feathering circuit is de-energized and the propeller is restored to its governing system where the blade pitch is varied to control speed. In the case of flame-out or turbine failure, several oscillations from negative to zero thrust take place as the propeller blade progresses to its new position. As can be seen from Fig. 9, this transition takes place rapidly but reduces the maximum value of negative thrust produced to approximately 8 per cent of the static take-off thrust for the condition shown and levels out at approximately 5 per cent. This value can be further reduced at the pilot's leisure by manually feathering the propeller and stopping the engine with the engine brake if provided.

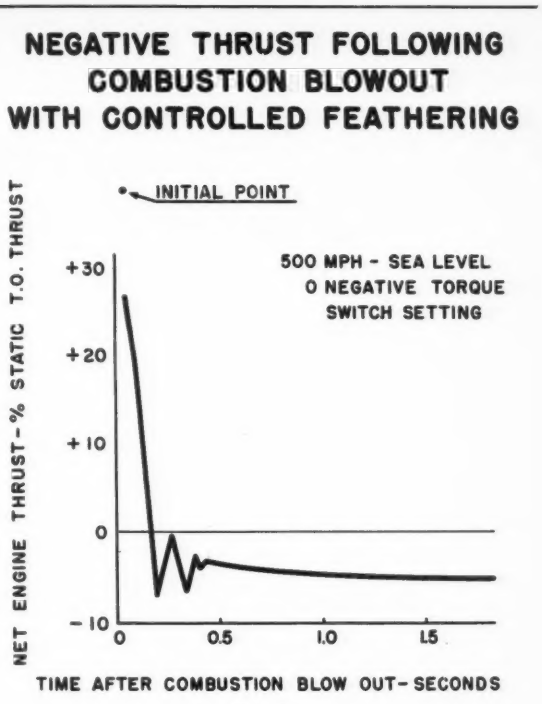


FIG. 9.

SUMMARY

In summary, it can be said that in certain speed ranges there are distinct advantages to a turboprop-powered transport over that powered by either the reciprocating engine or turbojet engines. With the development of higher pressure ratio and higher turbine temperature turboprop engines and the use of transonic and supersonic propellers, this useful flight spectrum will be expanded, improving fuel consumption at low speeds and increasing range, as well as decreasing the present speed advantage held by the turbojet. Development of the turboprop engine has proceeded at a more rapid pace in other countries than here in America, where the major effort has been expended on the turbojet programs. The introduction of American turboprop power plants in production versions of both military and commercial aircraft is scheduled for the near future and is indicative of the progress that is now being made. The principal problems facing the turboprop power plant are the development of a satisfactory, reliable, control system and an acceptable solution to the negative thrust problem which does not impose excessive limitations on engine design. Both of these are understood today, and solutions are available. Development work is still required, however, before these solutions can be sufficiently well proved for the turboprop to be considered as *the* engine to power tomorrow's transport. This can only be accomplished by additional flight testing. If it is to be accomplished soon, it will require continued support and sustained interest in the development of turboprop engines, controls, and propellers.

Conference on Supersonic Flow

An unclassified Conference on Supersonic Flow will be held in the Mathematics Building, University of Maryland, from 9:30 a.m. to 5:00 p.m. on March 19–20, 1954.

Information concerning the Conference may be obtained from Dr. E. L. Resler, Associate Research Professor, Institute of Fluid Dynamics and Applied Mathematics, University of Maryland, College Park, Md.

Design of the Transport Helicopter*

DAVID E. POSTLEt
Mohawk Airlines, Inc.

Discussion

In all sciences today, I think we should acknowledge that, while we are never too sure of what we think we know, it is what we do not know that is likely to prove the most embarrassing. This statement is particularly true in the transport helicopter field at this time, for no one has had any experience in the type and scope of scheduled helicopter passenger service that must be undertaken in the near future.

In spite of the fact that the scheduled air lines have rolled up a vast backlog of experience in operations, judging by the current controversy, it is difficult to clarify many of the requirements in the design and application of the jet-powered transport in the fixed-wing field.

In attempting to define clearly the requirements for the transport helicopter, however, we are dealing not only with an entirely new market in the short-haul field but also with many additional unknown factors that are not substantiated by experience.

Perhaps more than any other air line, Mohawk—one of the most successful of the 14 local service carriers—has devoted a great deal of study of the transport helicopter and its application to our route system. We are convinced that the helicopter is the one vehicle that will do the job that needs to be done in intercity transportation. Therefore, we are deeply interested in the design of the machine that is so vital to our operations and to the type of scheduled transportation we must provide. Based on our experience in the local service field and as a result of our extensive studies of the helicopter, I shall set forth as clearly as possible the design features that we believe must be incorporated in the transport helicopter, as well as the reasons therefor, in order that it may be successfully applied to scheduled air transport operations. These features are set forth as we see the requirements today, with full realization that time, development, and actual experience with the machine undoubltedly will change some of these concepts.

The flight characteristics of an aircraft determine the type of operation in which it may be profitably utilized. In this respect, the role of the helicopter in air transportation is clearly defined for some years to come, for it is especially qualified to provide transportation within the short-haul travel market. In order that we can tailor the design of the helicopter for this important sphere of operations, it is essential that we clearly understand the meaning of the term "short-haul market" insofar as operations are concerned.

The scheduled trunk air lines have specialized in long-haul travel of more than 400 miles. In the 12-month period ending June 30, 1953, the average length of passenger journey on our trunk air lines increased to a new high of 540.7 miles, which may be compared with the 195.3 miles average passenger journey on the 14 scheduled local service lines. Average length of passenger journey on Mohawk Airlines during the same period was only 167.5 miles, but this figure is significant in that we have achieved a service that can be termed "short-haul" with today's DC-3 aircraft. It has been estimated that almost 25 per cent of the trunk air-line passengers travel within the 100–199-mile bracket, and another 20-odd per cent is within the 200–299-mile bracket. In contrast, 80 per cent of Mohawk's traffic lies within the 125–200-mile bracket, and 7 per cent falls within the 25–99-mile bracket.

The efficiency of trunk air-line service increases as the average length of passenger journey is extended. In the local service industry, we realize that our future lies in our ability to reduce the average length of passenger journey. In fact, it is only by the reduction of this factor that we can achieve a significant penetration in the short-haul market. More specifically, with the transport helicopter, we must reduce average length of passenger journey to the 50–80-mile bracket, and the present average revenue per passenger for local service air lines must be reduced from $11 to $4.00 or $6.00. If this can be accomplished with the helicopter, air transportation—for the first time—will compete with the railroad, the motor bus, and even the private automobile.

This, then, is the so-called "short-haul travel market" within which the transport helicopter is destined to play an important role in air transportation, and we must bear these factors in mind in designing the machine to serve that function.

In my opinion, short-haul transportation with the helicopter will be conducted within two classifications: first, the metropolitan type of transportation conducted within an approximate radius of 50 miles from a large city, with helicopters operating over a series of radial routes extending to the surrounding suburban communities; and second, the intercity or local service type of transportation wherein helicopters will link the smaller cities together on routes between major ter-

Presented at the Rotating Wing Aircraft Session, Twenty-Second Annual Meeting, IAS, New York, January 25–29, 1954.

* Appreciation is due Robert E. Peach, Executive Vice-President, C. A. Benscoter, Vice-President—Operations; E. A. Butterfield, Superintendent of Maintenance; Remington R. Taylor, Superintendent of Communications; Edward C. Potter, Engineer; and to others in Mohawk Airlines for their assistance and suggestions in the preparation of this paper.

† Director of Research.

minals, such as one of the Mohawk routes connecting Buffalo, Albany, and Boston. While the metropolitan type of helicopter service has a considerable potential, our studies lead to the conclusion that the greatest and most productive role of the helicopter will be in the intercity type of operation.

From the trunk air lines, the local service air lines inherited the DC-3, which was originally designed for trunk air-line operations when average length of passenger journey was considerably less than it is today. It was the local service industry that introduced retracting steps in the entry door; 2- to 3-min. stops for loading and unloading passengers; carry-on baggage facilities and practices; the stopping of only one engine while loading at the passenger gate; the operation of passenger stations with the minimum of personnel; and efficient run-up, taxiing, and other procedures that—even today—either are not understood or not practiced by the trunk air lines. These features and procedures are vital to short-haul transportation and the reduction of overall operating expenses. As the transport helicopter comes into scheduled operations, the infiltration of new and additional methods of short-cutting costs and the efficient handling of passengers will become increasingly important.

The local service airlines are deeply concerned that they have a hand in the development of the transport helicopter, for they cannot again inherit a "second-hand" aircraft that was originally designed for trunk-line thinking and operations. For this reason, and because the helicopter is so clearly marked for short-haul transportation, the suggestions of the local service industry, with its more closely related experience in the development of this new market, should provide the most valuable yardstick in the design of the transport helicopter.

As a part of the overall problem of operating helicopters in scheduled air service, we must face the reality that for some time to come the direct operating expense of the helicopter will be more than that of the fixed-wing transport of comparable capacity. Likewise, the matter of indirect expenses of helicopter passenger service is no small problem, and its solution will not be easy. Short-haul operations require more ground stations and personnel. As average block distances are reduced, indirect costs mount at a rapid rate. Briefly, the problem of reducing direct operating costs rests primarily in the hands of the helicopter manufacturers, while that of indirect costs must be solved by the air lines. The solution of these matters will be found only in the close cooperation of the helicopter manufacturers and the air lines, as well as a clear understanding of each other's problems, and I have every confidence it will be done.

Fortunately, in the matter of direct operating costs, some of the unique flight characteristics of the helicopter accrue to its advantage over fixed-wing equipment. For example, it can operate safely at low altitudes and thus eliminate expensive climb to operating levels that are prohibitive in short-haul operations; it need not be subject to delays or circuitous routing often required by air traffic control; it need not fly extra miles in aligning its approach and departure paths with specific runways; ground taxiing can be practically eliminated; frequent stops can be made at greatly reduced cost per stop; and wheels, tires, and brakes will receive the minimum of wear and tear. These are important features of the helicopter from an operating point of view.

Before setting forth specific design features of the transport helicopter, and as a part of this overall air-line operating point of view, I would like to mention one other factor—safety. The scheduled air lines of the United States have achieved an outstanding record of safe operations. Analysis of the accidents that have occurred in air-line operations reveals that the majority occur in the vicinity of airports, either on approach or departure. Because local service air-lines land more frequently per route-mile operated, their exposure to possible accident is greater than in trunk-line operations. For this reason, I feel that the local service air lines have achieved a particularly commendable safety record. However, with the introduction of the transport helicopter to scheduled service, we must remember that the frequency of landings will be stepped up considerably and that a larger percentage of all flights will be operated over congested areas. Mark well this point—the public will not accept helicopter services presently planned, nor will any air line consider the helicopter as a replacement for its fixed-wing aircraft, if safety of operations is to be compromised in any manner whatsoever.

General Configuration

Now, in speaking of the transport helicopter, let us be clear as to the type of machine under consideration. First, it must have multiengined power, with sufficient reserve power to proceed safely with full gross load in the event one of its power units fails. Second, it should have a seating capacity of not less than 30 passengers. Third, provision should be made for a crew of three—a Captain, Copilot and Flight Agent. Fourth, it must have adequate provision for passenger baggage, cargo, and mail. Fifth, it should have a fuel range of approximately 200 miles.

I am sure that no one engaged in air-line operations today will question the need for multiengined power for scheduled passenger operations. With single-engined machines, safety will require operations to be restricted in order that a safe landing with passengers can be accomplished by any time. Such restrictions will preclude scheduling of flights during the hours of darkness over almost all types of routes. Unless a weight penalty is accepted for flotation gear, the single-engined helicopter must be operated at an unfeasible altitude over all water areas. Flight paths will continue to be circuitous over congested areas, and, certainly, instrument operations cannot be attempted with only one engine. In short, the necessity of completing

schedules under all operating conditions automatically eliminates the single-engined helicopter. Furthermore, it has been established by experience that the public will not accept single-engined flight equipment for scheduled air-line operations.

Mohawk has concluded that the ideal capacity of the transport helicopter engaged in intercity operations is one that will seat between 30 and 40 passengers. This figure has not been "pulled out of a hat." It is the result of extensive helicopter operating cost and revenue studies geared to our experience in local service fixed-wing operations. With a machine seating less than 30 passengers, seat-mile costs will be too high to permit establishing existing or nominal passenger tariffs over distances presently served with the DC-3, even if we take credit for limousine fares at each end of today's air-line journey.

While some operators have planned on the 16–20-place helicopter for the metropolitan type of operation, I believe that related seat-mile costs and the required passenger tariffs for such a helicopter will preclude sufficient penetration in the short-haul passenger market. In fact, it is difficult to forecast profitable operations, without excessive mail pay or some subsidy, in any type of scheduled passenger service with a machine providing less than 30 seats. The theory has also been advanced that smaller helicopters operated on frequent schedules will provide the answer to short-haul operations. Mohawk's experience clearly shows that this assumption is not correct, for successful short-haul passenger service is the result of a delicate balance between properly timed schedules at the hours people desire to travel, adequate capacity of the aircraft at peak travel hours, and load factors on each schedule operated. The moment the combination of these three factors becomes unbalanced, operating losses result.

When helicopters are operated on certain high-density routes, such as between New York and Philadelphia, it is probable that the desirable transport helicopter should have provision for at least 40 to 50 passengers.

Thus, with these considerations in mind, it appears that we should have two sizes of multiengined transport helicopters, one providing 30 to 40 passenger seats, and the other having not less than 40 to 50 seats. Each of these transport helicopters should have their prorated accommodations for passenger baggage and cargo, but the desired fuel range will be about 200 miles in each case.

I prefer to leave the question entirely in the hands of the helicopter manufacturers as to whether the transport helicopter should have one large main rotor, a tandem rotor system, or intermeshing rotors. Each configuration has its advantages; each has its disadvantages. Assuming that initial investment, maintenance, and overhaul costs, as well as parts replacement, are equal and provided one configuration does not impose an undue weight penalty over the others, then—insofar as the operator is concerned—it is performance that counts.

There is one extremely important condition that must be met in the transport helicopter. Center-of-gravity travel must be kept within permissible limits under any condition of indiscriminate loading. Passengers do not understand the need for blocking off certain passenger seats under certain conditions, the air line cannot extend its scheduled 2-min. stops for loading passengers and some cargo, while the crews decipher complex loading charts. Nor is it practical to transfer fuel from one tank to another or shift cargo in order to trim the ship. Thus, it is essential that a passenger may select any seat for his trip and that any normally expected load placed within the cabin—as long as it is within the gross limitation of the aircraft—will not displace the center of gravity beyond permissible limits.

Performance Characteristics

There are certain operating precepts regarding the transport helicopter in scheduled service which have a bearing on specific performance required: first, that there are no apparent conditions of safety that would require operation of the helicopter at more than 2,000 ft. above the ground, and that enroute altitudes 1,000 ft. or less are preferable for short-haul service; second, that, except for momentary hovering close to the ground immediately preceding landing or following take-off or unless an emergency requires the maneuver, there is no reason to include hovering in standard air-line procedures and practices; and third, that consideration of "power-off" autorotational characteristics is of minor importance when we consider the multiengined helicopter.

Even though direct operating costs per aircraft-mile are somewhat in direct ratio to cruising speed, high speeds over short-haul distances do not produce the saving in time expected. Mohawk is not so much concerned in clipping 2 min. from the flight time over a particular route segment as we are in having sufficient depth or range of cruising power to offset the severe effects of occasional 40-m.p.h. winds on maintaining regularity of schedules. In this respect, at 60 per cent of maximum continuous power for reciprocating engines or 70 per cent of take-off power for turbine engines, a cruising speed of 140 m.p.h. will be acceptable. Furthermore, we concur in the consensus of those attending the recent Helicopter Symposium at Puerto Rico that, with all engines operating, the helicopter should be capable of a sea-level initial vertical climb of 500 to 600 ft. per min. in standard atmosphere without wind and a minimum rate of climb of 200 ft. per min. at best forward speed with one engine inoperative at all altitudes up to 5,000 ft. above sea level.

Power Requirements

It has been historic with the fixed-wing transport that we have been in a continuing "nip-and-tuck" race between total engine power and gross weight.

Safety must not be compromised in helicopter passenger service, and, to this end, we must always provide for a greater reserve of power for added performance in the helicopter. When we speak of safety in aircraft, we speak of performance, and in adequate performance there is no substitute for power.

Let us consider the practical aspects of this principle. For example, assume that this added performance desirable in the helicopter requires 25 per cent more power. We might have to carry about 1,100 or 1,200 lbs. in added engine, transmission, and other air-frame weight in the 30-place helicopter, but it can be estimated roughly that the added power and performance would increase direct operating costs by only 3.5 cents per aircraft-mile. This additional operating cost would be partially offset by longer engine and transmission life between overhauls and perhaps by better insurance rates, and no passenger should object to paying 15 cents more per 100-mile trip for the added safety. This power reserve would also pay dividends in the event one power unit fails, for the remaining power could be utilized without requiring an unscheduled tear-down and overhaul of the engine that brings the aircraft home.

Power reserve and performance are closely related to the subject of heliports. One of the outstanding features of the helicopter is its ability to land in small areas. Without this characteristic it is doubtful that the helicopter would have received attention from the air transport industry, for we could not plan on supplying scheduled air service to the many communities throughout the country that either cannot afford to build an adequate airport or cannot build one because of terrain. If the multiengined transport helicopter should require landing areas 1,000 to 1,500 ft. long for safe take-off in the event of an engine failure, then it will be impossible to provide heliports where they must be located in order to perform the air service for which they are so well qualified. In this event, heliports will be relegated to the airport in the country, and we might just as well forget about the helicopter.

It is my opinion that we must have a transport helicopter that will have the performance necessary to land and take off safely from a heliport which is 250 to 300 ft. square, and certainly no larger than 250 by 400 ft. This size heliport will fit into a normal-size city block and will permit the selection of proper locations in almost any community. In setting forth these dimensions, I speak of the touch-down area required as apart from any area required for the parking of helicopters. When we consider the size of a heliport for a large city having multiple helicopter schedules, then adequate room must be provided, in addition to the touch-down area, for several machines to load simultaneously at various passenger gates. But here, too, unless we strictly limit the ground time to 5 min. (which should be ample) for each helicopter to load, I can foresee the undesirable need for tremendous heliports simply to provide ramp facilities.

I implore all who are connected with the helicopter industry and those who may be working on committees considering minimum heliport requirements, to face these simple, economic, and operating facts about the helicopter. Nor can we consider, from a practical point of view, flight procedures that would require a rearward take-off pattern, for how can such a crayfish departure be safely adapted to a busy therminal with other helicopters approaching the terminal at 1- or 2-min. intervals? Certainly, rearward take-off would demand far greater cockpit vision than any I have seen in the planning stage.

The answer to safety of operations which must be conducted from small heliports lies in the performance of the machine. I suggest your serious consideration of providing enough power in the transport helicopter so that, with full gross load, when one engine fails on a vertical take-off—the worst possible situation—remaining power would permit a vertical descent to a safe landing with no damage to the aircraft. Such a rate of vertical descent would have to be limited to well within the designed loading of the landing gear. This performance might require some additional power, perhaps as much as the 25 per cent mentioned above, but it probably would not amount to as much horsepower as might be required to hover with one engine inoperative. Such a reserve of power and performance in the helicopter would assure safe operations in almost any situation, and it would completely eliminate the rather sad graphic curves you have all seen which depict the safe take-off airspace that some feel to be necessary for the single-engined helicopter.

Operating Range and Fuel Requirements

I have stated that an approximate fuel range for the transport helicopter of 200 miles is desirable. This should be regarded as a minimum, and larger tank capacity should be provided in the event it is desired to operate over greater distances with less than full gross load. However, when speaking of fuel range, we should be more specific in order that we fully realize an important difference in the helicopter when compared to "fixed-wing thinking."

For example, Mohawk's helicopter route studies indicate that on intercity operations within our area the average block distance between heliports will be about 27 miles. This figure is an arithmetical average over an entire route system, whereas the actual operating average block distance would be about 35 miles when "skip-stop" or express schedules are considered. Provided that fueling can be quickly accomplished, we believe it will be convenient to schedule refueling stops approximately at every fifth heliport. Thus, in computing fuel range required—rather than estimating fuel on a nonstop basis for the 200 miles at a higher block speed—we would compute the fuel load on the block speed over 35-mile distances with allowance for five 2-min. stops enroute.

With a helicopter cruising at 140 m.p.h., block time over the 200-mile range in 35-mile flight increments, with five 2-min. passenger stops, would be about 1 hour

and 42 min. With regard to reserve fuel supply, consideration of the helicopter is different from the fixed-wing transport, and we feel that a 30-min. fuel reserve will be ample. Thus, the fuel required for this type of helicopter over a 200-mile range should provide for at least $2^1/_4$ hours of flight time.

When necessary, Mohawk often accomplishes the refueling of its DC-3's within 5 min., and we see no reason why fueling stops with the helicopter should require any additional time. With the fixed-wing transport, aircraft parking problems result in the use of fuel trucks that consume precious time maneuvering into position, and refueling crews must use ladders to reach the fuel caps. These costly procedures must be entirely eliminated in the transport helicopter, and it is important that connections for fuel hoses be provided within easy access from the ground without ladders. Similarly, fuel pits at heliports must be conveniently located so that fueling can be accomplished quickly while passengers are being loaded.

Maintenance and Accessibility

Much has been written and said regarding the importance of accessibility to all component parts of the helicopter to speed up inspection and overhaul. I need not further expand this subject, except to highlight a few related points.

Mohawk, like several other air lines, has instituted a phase or progressive overhaul system with our fleet of DC-3's wherein portions of major tear-down and overhaul of the aircraft are accomplished during each of eight periods of shop time. With this system, each aircraft is tied up in the shop for shorter periods, the labor load is spread more evenly, and more efficient stocking and purchasing of replacement parts is permitted. Perhaps some of this phase overhaul system will be applicable to the helicopter, but at this time we anticipate that considerable changes will be necessary in our shop routines and scheduling. It will be of great advantage to helicopter operations—assuming quick interchangeability of all component parts—if tear-down, inspection, and overhaul can be set up on a production basis within the shop. Components due for inspection and overhaul can be quickly replaced by overhauled units, and the majority of such work can be accomplished under more efficient working conditions, rather than on work stands around the aircraft which are costly in man-hours of labor. With such a system, it would be entirely possible to place the transport helicopter in the shop at midnight, and by early the next day it could be returned to service with the "clock turned back to zero" on all components.

In this manner, it is probable that daily utilization of the transport helicopter can greatly exceed today's possible utilization of the fixed-wing transport. Higher utilization of aircraft is reflected in reduced direct operating costs. Therefore, quick-change of components is of great importance.

The helicopter industry is rather unique in that required direct maintenance is expressed in terms of "man-hours per flight hour." Certificated scheduled air lines must follow the uniform accounting procedures established by the Civil Aeronautics Board. Accordingly, we have a wealth of data which expresses all operating costs in "cents per revenue-mile," but with that system it is almost impossible to calculate accurately man hours of labor per flight hour for the fixed-wing transport. In our studies of the helicopter, we needed such a figure for comparative purposes and went to considerable work, digging through shop orders and related material, to secure the data. It may be useful to you to know that, during the 12 calendar months of 1952 with Mohawk's fleet on DC-3's, man-hours of direct maintenance labor per flight-hour fluctuated from a low of 4.27 hours to a high of 8.78 hours, and averaged 5.15 hours for the year. This included all direct maintenance labor except for engine and propeller overhauls.

Retractable Landing Gear

With the cruising speed of 140 m.p.h. now possible with the transport helicopter, partly as a result of retractable landing gear, the question arises as to whether the advantages of a retractable gear make it a desirable item of equipment for intercity operations where average block distances—according to our studies—will be about 35 miles. An exact answer to this question is almost as difficult as trying to tie a firm knot in a slippery eel.

We can assume that the inspection, maintenance, overhaul, and replacement parts for a retractable gear in a 30- to 40-place helicopter would be the same as that for a DC-3. It might also be assumed that the 140-m.p.h. cruising speed of the helicopter would be reduced to 120 m.p.h. with the gear down. The cost and variation of speed, due to retraction or nonretraction of the gear, must be related in turn to time saved and direct aircraft operating costs over varying block distances.

Without any claim to positive accuracy in the solution of this pinball type of equation, it is my opinion that, with the transport helicopter, it would be profitable for the pilot to retract the gear in all block distances exceeding 9 miles, and that the retractable landing gear will pay dividends to the operator in intercity average block distances. Needless, to say, however, we must have a positive and easy auxiliary method of extending the gear, for a belly landing with a helicopter would result in excessive damage as compared to such a landing in a fixed-wing transport.

Fire-Extinguishing Equipment

Safety will require the same type of pressurized fire-extinguishing equipment for engine nacelles as that provided for today's fixed-wing transports. However, because of the flight characteristics of the helicopter and its ability to descend and land quickly at almost

any place in an emergency, as well as its operation at relatively low altitudes, consideration should be given to a relaxation of present T-Category requirements for fire-warning devices which may not be justified in the transport helicopter. The usual type of hand-operated fire extinguishers should be provided for the cockpit and cabin, while the required inclusion of parachute flares, in my opinion, would increase fire hazard and would be of no value to the helicopter.

Cabin Pressurization

Cabin pressurization is essential to the operation of the modern high-speed fixed-wing transport, for it permits comfortable flight at high altitudes and at rapid ascent and descent to and from cruising altitudes. But with the helicopter, normally operating not in excess of 2,000 ft. above the ground, I see no need for cabin pressurization—even in operations over our high Western plateaus. Certainly, with its weight and high cost of installation and maintenance, cabin pressurization is one item of equipment which should not be included in the helicopter.

Some have proposed cabin pressurization in order that rapid descent to landing can be made without passenger discomfort. Time saved in rapid descent from an altitude of 1,000 or 1,500 ft. is insignificant. Furthermore, it has not been found necessary to install pressurization in the elevators operating in the Empire State Building, and these elevators are capable of descending at 1,000 or 1,200 ft. per min.

Cockpit Standardization and Vision

Simplification of controls and arrangement of the necessary equipment in the cockpit is of importance in relieving the pilot of the considerable task of monitoring cockpit "gadgets" so that he may devote greater concentration upon the fulfillment of his responsibility for the safe conduct of each flight. In this respect, standardization of cockpit design is of deep interest to us.

Although at this time we are not certain as to the type of navigation aids that will be adapted to scheduled helicopter operations, other cockpit controls and equipment are now well defined, and it is not too early to start the ball rolling on cockpit standardization. I hope that such standardization will be accomplished not by engineers alone but with the help of pilots qualified in the air transport field and experienced in the flight of helicopters.

If I were to select the outstanding error that has been made in the design of the fixed-wing transport—the error that is common to all—I would select the matter of cockpit vision. It has been historic, perhaps to some extent due to all of the instruments and equipment assigned to the cockpit, that pilot visibility has been sadly neglected. Because of the maneuverability of the helicopter, the precision with which it can be flown, and the manner in which it will be operated, we must not ignore or forget this important subject, nor can we compromise on this point in design. Our objective in design should be to provide the pilot with a view from the cockpit equal to that of a goldfish from the familiar bowl. This expanded window area necessarily directs additional attention to efficient defrosting apparatus.

Passenger Loading Doors

The location of adequate passenger doors is important in the interest of efficient passenger loading during the short stops at each heliport, and for 30 to 50 passengers, we believe that one entrance and one exit door should be provided.

Mohawk does not ask its local service passenger to accept the time-consuming process of checking and claiming his baggage unless he specifically desires to do so, and almost all passengers prefer to handle their own baggage. The carry-on baggage feature is a definite requirement in helicopter operations. It follows, then, that the passenger should place his baggage in a convenient rack immediately on entering the aircraft, otherwise the aisle space becomes unnecessarily crowded when luggage is carried to locations adjacent to the passenger's seat. Crowded aisle space does not facilitate passenger handling. Similarly, the passenger should pick up his bag immediately prior to stepping out of the cabin door. Thus, the carry-on baggage procedure is an important consideration in the proper location of passenger entrance and exit doors.

If, as proposed at the Puerto Rico Helicopter Symposium, the passenger enters a door at the rear of the cabin and makes his exit at the front, or vice versa, then—no matter where the baggage carry-on rack is located—his bag will always be in the wrong place. Such a location of doors would result in the passenger, at one time or another, carrying his baggage the entire length of the aisle, or—when other passengers are entering—he would be crowding past them in the opposite direction to get his bag.

Some of our helicopter friends in the United Kingdom have suggested that a door be placed opposite each row of passenger seats, just as in many of the European railway coaches. This proposal would certainly facilitate the passengers getting in and out, but I fear that the weight of so many doors and their actuating mechanisms, as well as maintenance, would be prohibitive; not to mention the complex system of warning lights that would be necessary in the cockpit.

Mohawk's experience in quick-stop passenger loading leads us to the conclusion that the desirable location for the passenger doors is at the center of the cabin length, with the entrance and exit doors joining in the center or separated only by a very narrow mullion; the mullion is less desirable in order to have the widest opening possible for emergency cargo when needed. The exact location of the doors may be adjusted within reasonable limits to take advantage of the protection afforded from the weather by overhead stub-wings, which may be part of the helicopter's configuration.

The carry-on baggage rack should be located opposite these passenger doors, and cross-cabin bulkheads should separate the entrance-and-baggage vestibule from the passenger sections of the cabin, fore and aft, to exclude cold winter drafts from direct contact with the seated passengers and to improve the appearance of the interior. This arrangement avoids the necessity of carrying baggage in the aisles at any time, keeps the baggage where it should be—immediately adjacent to the doors—and reduces by one-half the volume of passenger traffic in the aisles as compared to that which would be experienced if the doors were located at the forward or rear end of the cabin.

Entrance and exit doors should be of the sliding type, quickly actuated by electric or hydraulic means and controlled primarily from the cockpit with a secondary control in the entrance vestibule for the flight agent. Passenger access to the cabin will be expedited if the cabin floor is located as close to the ground as possible. Any steps necessary between the cabin and ground should be extended or retracted simultaneously with the opening or closing of the doors; of course, the fewer the steps required, the less the weight. If several steps are necessary, then handrails for the steps become an essential item.

As a matter of information, the DC-3 cabin door is $26^1/_4$ in. wide and 57 in. high at its maximum points. We recommend that each cabin door for the transport helicopter be at least 30 in. wide and 60 in. high, and preferably 32 by 66 in. The bottom of the DC-3 door is 46 in. above the ground, and we would like to have the helicopter door as low as 16 or 18 in. from the ground. Incidentally, the cabin floor of the DC-3 inclines at an angle when the aircraft is on the ground, and we urge that every effort be made to keep the cabin floor of the helicopter level when on the ground, for this will avoid the hazard of slipping in the aisle when snow or rain is tracked into the cabin, and it will make possible a greater flexibility in seating arrangements as may be desired by the various air lines.

Now, in proposing the location of passenger entrance and exit doors at the approximate center of the cabin, I realize that such an arrangement displaces the passenger load to an extent that difficulty may be encountered in c.g. displacement. In this event, I would suggest a double-deck passenger cabin similar to that employed in the Boeing Stratocruiser, and with such a configuration we see no serious operational problems. Double-decking is a preferable alternative to the blocking off of passenger seats or to computing c.g. location prior to each take-off.

Carry-On Baggage Rack

Of all passengers carried by Mohawk Airlines, only 22 per cent transfer to or from other air lines at various points of connection, and normally it is the transfer traffic that carries the greatest weight in baggage. While our free baggage limit per passenger is 40 lbs., the actual average baggage weight per passenger is only 20 lbs. I think our experienced average weight for passenger baggage would be representative of that of all local service air lines, and I believe it is a practical weight allowance that can be applied to intercity helicopter operations.

Mohawk has completely redesigned the interiors of its DC-3's, and we have applied our experience with passenger baggage to the provision of an appropriate carry-on baggage rack, located directly opposite the entrance door. In this installation, we have provided three shelves, counting the cabin floor as one shelf, which are 80 in. long. These shelves are $33^1/_2$ in. wide for 43 in. of their length, and then taper to a width of $19^1/_2$ in. because of other installations in the DC-3. Total area of the three shelves is 50.4 sq. ft., which averages 1.94 sq. ft. per passenger seat. From floor to the top of the baggage rack, the shelves are spaced at 16-, 28-, and 21-in. intervals, respectively. Total cubic contents of the baggage rack is 91 cu. ft. or 3.5 cu. ft. per passenger seat.

Mohawk's carry-on baggage rack is entirely satisfactory for our operations, and the data as to average weight of passenger baggage, area, and cubic space required should provide excellent yardsticks for intercity helicopter operations.

Passenger Accommodations

For some time Mohawk Airlines operated its original DC-3's with the 21-seat configuration inherited from trunk air lines. We were not satisfied with the seating arrangement because the passenger load was too far aft, and until full loading conditions were approached, rear seats had to be blocked off because of c.g. difficulties. Passengers do not understand this necessity for blocking off the seats they prefer to occupy. Furthermore, the carry-on baggage rack was too small, while there was no provision for hanging up the passenger's heavy winter coat, which is too bulky to be placed in the overhead racks when all seats are occupied.

Accordingly, Mohawk has refurbished the interiors of its DC-3's during the past several months at considerable expense. It was accomplished only after extensive study of the problems involved and the greatly improved effect desired. We moved the entire passenger load forward and it is no longer necessary to block off passenger seats. We installed new upholstery in carefully planned and harmonizing colors to create the effect of a larger cabin. We added new soundproofing, new window curtains, new floor mats, and electric fans; provided a new coat rack; installed the carry-on baggage rack described above; and provided 26 new passenger seats.

After the first DC-3 had been completely refurbished, we placed it in service and immediately conducted a passenger survey to learn what the passengers thought of it. Passengers were enthusiastic, and we learned some additional interesting points from the survey. Many passengers liked our new DC-3 interior and arrangement better than any other air transport air-

craft they had been in; they commented on the improved soundproofing, and some even thought it flew more smoothly and faster than the old DC-3's. Mohawk is proud of its accomplishment, for we have not only developed what we believe to be the finest DC-3 for local service operations, but we now know what we want when it comes to the helicopter. Perhaps the helicopter industry can profit from our experience, and if you doubt the effect that has been produced in the DC-3, I invite you to inspect our aircraft at any time.

For soundproofing, we removed the old material, which often absorbs enough moisture to increase the weight of the DC-3 by more than 100 lbs., and cemented a quilted blanket material, having a Fibreglas base, against the metal walls. This material is $^3/_{16}$ in. thick and weighs about 1.7 oz. per sq. ft. Over this was installed a $^3/_4$-in. layer of Fibreglas soundproofing insulation having a weight of about $^8/_{10}$ oz. per sq. ft. Finish upholstery on walls and ceiling is a thin plastic material weighing about 2.4 oz. per sq. ft. Total weight of soundproofing and upholstery on walls and ceiling is about 4.9 oz. per sq. ft. On the floor, a new plastic material was used that withstands wear remarkably, has an insulating pad cemented to its under side, and weighs about 7.2 oz. per sq. ft.

I am unable to express in decibles the degree to which interior noise has been reduced, but if this noise level can be attained in the transport helicopter, it will be satisfactory. If necessary in the helicopter, because of gear noise, additional Fiberglas insulation could be installed to produce the desired result with very little weight penalty. Because the configuration of each helicopter will present its own peculiar problems in cabin noise insulation, I suggest that the manufacturers assume the responsibility of providing the insulation necessary and include this material in the empty weight and price of the machine, leaving to the operator the selection and added expense for the finish upholstery material only.

Mohawk has installed a standard make of passenger seat with adjustable back rest. Each seat provides space for 2 passengers, has a removable arm rest in the center, is padded with foam-rubber cushions, and is finished with a heavy wool fabric. The seats are arranged for four-abreast passenger seating with an aisle that tapers from 17 to 13 in. wide. Overall width of the double seat is 39.5 in., depth from front to back is 24 in., and spacing from back to back is 40 in. Weight per seat, including safety belt, cushions, and upholstery, is 42 lbs., or 21 lbs. per passenger.

These seat dimensions and spacing are recommended as a minimum for the transport helicopter. However, to expedite passenger loading, Mohawk recommends that the aisle width be increased to 18 in. and that the double-seat width be 44 in. This would require a cabin 106 in. wide at its maximum point, and the ceiling height over the aisle should be not less than 78 in.

With regard to passenger comfort in the transport helicopter, I have heard many suggestions for lightweight seats, perhaps made of a plastic wicker, with little or no upholstery; and some have suggested bench-type seats extending the length of the cabin. While the transport helicopter will provide sort of an intercity aerial bus service, I cannot agree with these suggestions for passenger seats. Even intercity bus lines, such as Greyhound, have had to furnish comfortably upholstered seats for their buses, and we also will have to assure the passenger's comfort, even though the average length of ride may be only 30 or 45 min. The seats and spacing I have mentioned are not "superplush" but supply the degree of passenger comfort we believe to be essential, and the foam-rubber cushions and plastic upholstery material will take a lot of punishment. There is one compromise on these seats that I would suggest, and that is the elimination of the reclining feature of the back rest. This would save a little expense, about 1 lb. in weight and would allow spacing of the seats to be about 38 in.

Experience with the helicopter probably will prove that it is unnecessary to design helicopter seats and safety belts to the high G-loadings now required for seats in fixed-wing aircraft, but at this time it appears that relaxation of these design factors would not save much in cost or weight, and lighter seats may entail excessive maintenance.

Cabin Windows

Primarily because of pressurization, it has been necessary to utilize small windows in the cabins of modern high-speed aircraft; but these windows certainly give one the impression of being sealed in a tube and shipped off to places unknown with little regard to the passenger's pleasure enroute. Because the helicopter inherently is a low-flying vehicle, we should capitalize on the unusual and excellent view of this country, which can add much to the passenger's enjoyment of his flight and will contribute greatly to the helicopter's popularity.

The net size of the DC-3 cabin window is 16 in. wide and $10^3/_4$ in. high. Such small "peep holes" should be expanded in the helicopter to not less than 34 in. wide and 24 in. high, with the bottom of the window set about 26 in. from the floor, or just above the arm rest of the passenger seat.

In lieu of large individual windows opposite each row of seats, I suggest your serious consideration of an even better alternative. Let us have a continuous window along each side extending from front to rear of the entire passenger cabin. This should not present undue weight or structural problems, and structural members supporting the cabin floor would not be objectionable if they are exposed, properly spaced, and extend past the window area.

The importance of large windows in the passenger cabin cannot be overemphasized, and, regardless of the difficulties, they must be provided in the transport helicopter.

Other Cabin Equipment

In addition to the above accommodations, other features are essential to passenger service. A coat rack should be provided adjacent to, or within, the entrance vestibule, and we suggest a simple supporting bar with the minimum capacity of $1^1/_2$ in. in length for each passenger seat.

A small seat and safety belt for the flight agent should be located adjacent to, or within, the entrance vestibule. The flight agent in helicopter passenger service will have added responsibilities, and although we believe one flight agent can handle 30 or 35 passengers, it is probable that two flight agents will be necessary for the 40- to 50-passenger helicopter. A weight allowance of 10 lbs. is adequate for each flight-agent seat.

A toilet and lavatory will be necessary equipment in the transport helicopter, and although one will be sufficient for the 30-place machine, two lavatories for the 50-place transport probably will be needed.

Complete buffet equipment for serving meals certainly is not required in the helicopter. However, provision should be made so that a small bar could be installed to implement the serving of coffee if desired by the air line. This added touch to passenger service is popular and costs the air line but a small amount per passenger.

Mohawk has found the combustion type of cabin heater to be the most satisfactory source of heat for cold weather operations. The combustion heater should be equipped with high-velocity blowers for adequate heating of the cabin while on the ground, and these blowers should also be available for ventilation of the cabin and complete circulation of air while the aircraft is on the ground during warm summer weather. Incidentally, cabin heat should be ducted into the lavatory rooms to prevent water in storage tanks from freezing.

Cargo Accommodations

It must be acknowledged that the hauling of cargo over short-haul distances is an entirely new field that has not been fully developed by the air transport industry. Full development of the cargo potential in intercity helicopter service will require re-examination of present commodity rates in order that we can supply fast transportation of shipments over short distances in price competition with present surface carriers.

Cargo space in Mohawk's DC-3's, located at the aft end of the cabin, is 73 in. long, has a maximum width of about 70 in., and extends the full height of the fuselage. This space will accommodate an approximate average of 1,600 lbs. and is serviced through an exterior door 31 in. wide and 43 in. high, located 36 in. from the ground. An additional and larger door has been installed between the cabin and cargo compartments to expedite loading. Mail, express, and freight shipments are normally carried in this cargo space, as well as some checked luggage. But because of the size of the cargo loading doors, Mohawk has placed a size limitation on shipments of express and freight; and because each station is operated with the minimum of personnel and ramp equipment, the weight of each package received for shipment is limited to 100 lbs.

Insofar as we can foretell at this time, the transport helicopter should have about the same space and weight capacities for mail and cargo as provided in the DC-3. If necessary, the cargo space can be divided into two compartments located fore and aft of the passenger cabin. In order to facilitate loading, the exterior door to the cargo compartment should be at least 32 in. wide and 48 in. high, and it should be located close to the ground level, certainly no more than 30 in. from the ground.

There is little doubt that passengers will be the prime source of revenue in intercity helicopter service, and it would be inadvisable to delay a passenger service by the loading of large cargo shipments. Furthermore, a somewhat increased frequency of scheduled service should be provided with the helicopter as compared with those operated by local service air lines today. For these reasons, if weight allowance requires some compromise, I would suggest that the total allowable weight for cargo with a full passenger load could be reduced to 1,000 lbs., but in this event the space for cargo should not be reduced.

External Noise

In speaking of the performance of the helicopter, I stressed the need for operating into small, conveniently located heliports. Closely associated with this subject, and of almost equal importance to performance, is the problem of external noise produced by the helicopter. Every effort must be made to make the helicopter operate quietly, and if this is not accomplished, we will not be permitted to serve heliports in the centers of cities because of the nuisance factor.

With the airplane, approximately 80 per cent of the noise emanates from the propellers. Even if airplane engines were muffled, noise would not be reduced to an acceptable degree unless some method were devised to quiet the operation of the propeller. We have an entirely different situation with the helicopter. If we muffle the noise of engine exhaust, which probably accounts for 90 per cent of the total, the remaining 10 per cent caused by the rotor system would not be objectionable.

I am also somewhat dubious about satisfactory results if we depend upon the blending of helicopter noise with a certain level of prevailing background noise normal to large city traffic, for Mohawk will operate the helicopter into rather quiet country communities, as well as metropolitan areas.

I am sure that the ingenuity of our helicopter manufacturers will provide the answer to eliminating objectionable external noise in the operation of the helicopter. I hope it can be accomplished within a weight allowance of 0.1 lb. per hp., with a power loss not exceeding 2 per cent. If it would be of assistance

in solving the problem, a cutout could be installed on the mufflers which could be opened when operations are conducted over less populated areas outside of cities. In the event gas-turbine engines are used to power the transport helicopter, I understand that the problem of reducing engine noise will be somewhat simplified; conversely, I suggest that the problem will become greatly magnified if jet power plants are considered.

Special Features of Main Rotors

Just as the metal-bladed propeller has become essential equipment of the transport airplane, I believe the all-metal rotor blade is essential to scheduled helicopter operations. In this respect, I am greatly encouraged with the rapid progress and the success achieved by Sikorsky and Piasecki with their all-metal rotor blades, and it is important to note that it is now possible to install one new blade in a rotor system without upsetting dynamic balance, as compared with the older practice of mating the blades in sets which requires the exchange of all rotor blades.

Flexing of the rotor blades and centrifugal force are excellent deicing factors; but if deicing equipment is necessary, all-metal rotor blades can be easily adapted to the injection of hot air. Thus, the matter of icing of the rotor system should not present any insurmountable problems. In fact, the installation of equipment for the prevention of ice on rotor systems should be much more simple and economical to maintain than such equipment for the airplane propellers and wing surfaces.

It should be possible, with the transport helicopter, to quickly fold the rotor blades back over the fuselage. Some have suggested the frequent need for folding of the rotor blades and have strongly supported folding them by mechanical means. Mohawk plans on using the folding rotor blade feature only when the helicopter is placed in the hangar for maintenance or overhaul. Accordingly, we will be pleased if the rotors can be folded manually within a few minutes, using rotor "carry-jigs" if necessary. We are not inclined to pay for mechanically folding rotor blades in initial cost, in weight penalty, or in maintenance. The small cost of the manually operated folding blade feature will be offset a hundred-fold in required hanger space for a fleet of transport helicopters.

Conclusion

In conclusion, I should like to highlight one or two points. Much has been said about the importance of the helicopter in times of national emergency and about the great public service it can provide in the event of an atomic attack on any of our metropolitan areas. I am sure that, in such emergencies, any air line would be anxious to place its fleet of transport helicopters at the disposal of the public need. Air-line helicopter services, personnel, and know-how at such times would be of untold value to our national defense and, perhaps, to our very existence.

In addition, serious local emergencies occur each year, such as tornadoes, hurricanes, floods, epidemics, train wrecks, and highway accidents, wherein a fleet of transport helicopters could render invaluable service to the public and in the saving of human lives. In fact, I can foresee certain conditions where the helicopter may be the only means of travel available as a result of the snow and ice storms common in certain areas.

These are some of the reasons I have suggested adequate passenger loading and exit doors, the provision of reserve power and performance, and the use of cargo doors of ample size to provide ease of loading. As I interpret statements made by representatives of our military services, many of the design features suggested here would have their full endorsement.

I am convinced that there is little difference, if any, in the basic requirements for the transport helicopter for scheduled air-line service and the machines needed for military service except for subordinate equipment that can be removed or installed for either use. Therefore, it is important in the interest of the earliest development of the transport helicopter that there be full and complete coordination and exchange of information regarding its design and performance characteristics between the military services and the scheduled air lines. Certainly, it merits the support of our Federal Government at every opportunity.

If the transport helicopter has the necessary reliability and ease of maintenance and the adequate power and reserve of performance suggested here, Mohawk Airlines believes that the helicopter will play an extremely important role in transportation and in national defense which will exceed in opportunity and volume any service heretofore performed by the aviation industry.

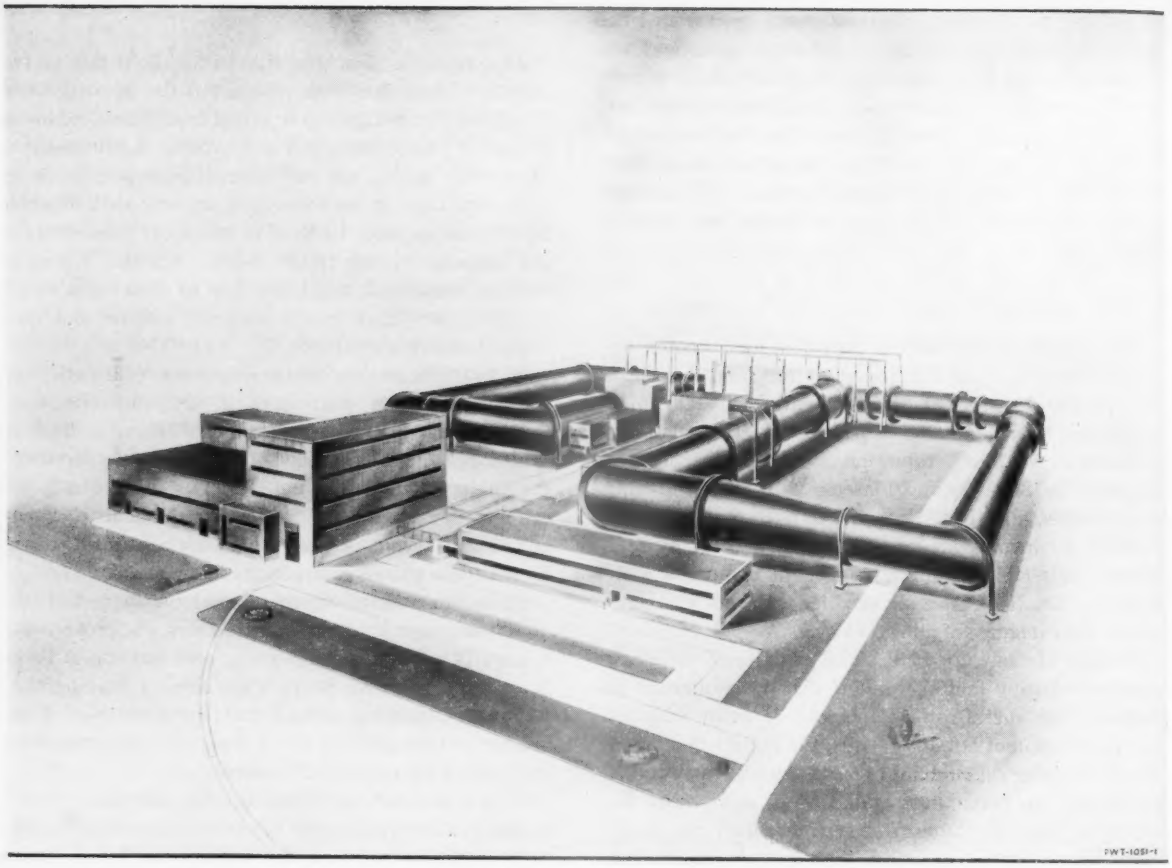


FIG. 1. Artist's conception of the Propulsion Wind Tunnel as it will look when completed. Transonic circuit is at the left; supersonic circuit is at the right. Both tunnels are powered by one set of drive motors, totaling 216,000 hp.

The World's Largest Wind Tunnel

W. J. WALKER*

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INTRODUCTION

THE WORLD'S LARGEST WIND-TUNNEL FACILITY is now under construction at Tullahoma, Tenn., at the U.S. Air Force's Arnold Engineering Development Center. When completed in 1955, the new tunnel will be used primarily to investigate internal and external aerodynamic characteristics of full-size jet engines and for aerodynamic testing of air frames and guided missiles.

The facility (called the Propulsion Wind Tunnel, see Fig. 1.) is arranged in two separate closed-loop circuits, a transonic and supersonic, with duct diameters ranging from 36 to 55 ft. A common 216,000-hp. drive is located between the two loops. The Propulsion Wind Tunnel is designed to provide air speeds in the two 16- by 16-ft. test sections from Mach 0.8 to Mach 3.5 (more than 2,500 m.p.h.).

One three-stage compressor will be used in the transonic loop. The compressor for the supersonic tunnel will have 18 stages arranged in four tandem cylinders with an annular by-pass duct around the last three; this compressor forms practically one complete "leg" of the loop. Air is directed through these last three compressors or into the by-pass by large iris valves.

COMPRESSOR SELECTION

In the original planning, a 20-stage compressor to serve a single tunnel having two parallel throats (one supersonic, one transonic, with huge valves for isolating one while the other was in use) was considered. However, the final decision was to use two separate compressors in separate tunnels with a common drive system between them. The change was made to permit

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operation of both the transonic and supersonic test sections at the same time, whenever their combined demand is within the rating of the drive system. This was intended to improve the "utilization factor" of the facility, since it would have been impossible to use two parallel throats simultaneously because of flow balancing and valving difficulties. In addition, the cost of the huge isolating valves was believed to be comparable with that of a complete separate tunnel, and the technical complications of the valves were considered greater than those for a separate transonic tunnel.

Specifications for the compressor and drive system require not only a very high maximum volume flow (more than 13,000,000 cu. ft. per min.) through the compressor but also a very wide range of volume flows (almost 2 to 1). At the same time, compression ratios range from more than 7.0 down to 1.06 and tunnel pressures from practically zero to $2^1/_2$ atm. absolute.

Anticipated tunnel requirements also demand: (1) high horsepower at both low and high compression ratio; (2) high horsepower at both low and high volume flow; (3) that flow characteristics from one tandem compressor cylinder to the next and from compressor to tunnel be "matched" to avoid dangerous stalling of any stage under any specified flow condition; (4) high drive-system efficiency; (5) high operating power factor; (6) minimum "dead" time (time required to start, stop, change drive and compressor configuration, etc.); (7) avoidance of large gears; (8) low shaft-seal leakage; (9) flexibility; and (10) simplicity of arrangement and control.

Optional methods for obtaining the required wide range of flow capacities and pressure ratios were: (a) drive-speed variation; (b) stator blade-angle variation; (c) rotor blade-angle variation; (d) by-passing or valving; (e) operation of multiple compressors in series-parallel or a tandem configuration; and (f) feasible combinations of these methods.

Variation of compressor speed is frequently used as a means of varying discharge pressure (test-section air speed) in existing wind tunnels. Why not use it for the Propulsion Wind Tunnel? For one thing, reducing compressor speed not only reduces the compressor discharge pressure but also reduces the flow volume produced according to a fixed (fan) law. This fixed relationship between rotative speed, pressure, and flow volume is inconvenient when it is desired to increase volume flow as compressor discharge pressure is decreased. Since this is required by P.W.T. operating plans, variable-speed compressors are not suitable. Also, to achieve the greatest possible utilization of installed horsepower, volume flow must be increased as pressure ratio (or more exactly, "pressure boost"*) decreases. This is true since compressor horsepower is proportional to the product of volume flow (cu.ft. per sec.) times pressure boost (lbs. per sq.ft.).

To accomplish this volume variation at low, as well as high, pressure ratios, a constant-speed machine having adjustable stator or rotor blades is required. For the P.W.T., stator-blade-angle control was selected. Stator and rotor blade-angle variation are fundamentally similar so far as their respective effects on discharge pressure and volume flow are concerned. However, mechanisms for accomplishing stator blade control on a multistage, multiblade machine are mechanically much simpler than equivalent mechanisms for accomplishing adjustment of rotor blades. If the rotor is a single row of large blades similar to airplane propeller blades, and where stator blading is either simple or nonexistent, constant-speed volume-flow adjustment can be accomplished by varying rotor blade angles through a mechanism similar to that used on variable-pitch propellers. But, if the rotor carries many rows of many blades each, they cannot be arranged as simple propellers, and stator blade control becomes mechanically simpler than rotor blade control. Also, it is possible to design aerodynamically rotor and stator blading so that the greatest twist, taper, and camber occur on the rotor blades while holding relatively simple geometry on the stator blades. This, naturally, is desirable when designing for controllable stator blades. The reverse design—making rotor blades simple and stator blades complicated—does not simplify the problem of rotor blade control in a multistage, many-bladed machine because of the complexity of the rotor structure itself.

By-passing or valving a portion of the airflow volume produced by the compressor is one way to match the compressor characteristic to the tunnel characteristic. It frequently happens—in wind-tunnel systems that cover a wide range of flow volumes and pressure ratios—that the volume of air which will flow through the throat with a given pressure difference across the throat is less than the volume of air which the compressor will produce when pumping against this same pressure differential. This is especially true of compressors that rely upon speed variation as a means for varying pressure. To overcome this difficulty, an airflow path can be established in parallel with the throat (operating across the same pressure differential as the throat) to carry the excess air. Thus the compressor operates at the given pressure ratio and one volume flow, while the throat operates at the same pressure ratio and a different volume flow—the differential flow being carried by the by-pass. However, this represents a direct loss of power, and extra expenditure for ducting, valves, etc., which can be fairly large for a tunnel of the capacity of the P.W.T.

Again, by stator blade-angle variation, a fairly wide percentage range of volume flows can be produced by the compressor at essentially constant compression ratios, thus permitting the original tunnel flow-pressure ratio requirements to be met without wasting power and airflow in a by-pass.

* "Pressure boost" is defined as the difference between discharge and inlet pressure ($P_{out} - P_{in}$), whereas pressure ratio is the ratio between discharge pressure and inlet pressure (P_{out}/P_{in}).

FIG. 2. Schematic drawing of the transonic compressor, the drive motors, and the superonic compressors. A simplified electrical diagram for one set of motors is shown. At the right in this diagram is the d.c. braking arrangement. In the supersonic compressor circuit, one iris valve is shown in a by-passing position.

However, recent developments in wind-tunnel art have made possible higher speeds for a given compressor ratio by use of a second throat in series with the first. The planned use of a second throat such as this in the P.W.T. supersonic tunnel will so restrict airflow that a by-pass will be required. (This series throat is entirely different from the parallel throats discussed earlier.)

Operation of multiple compressors in series-parallel can also be used to cover a wide operating range of volume flows and pressure ratios. In such a system, compressors are operated in parallel to obtain large volume flows at low compression ratios, and in series to obtain high compression ratio at low volume flows, in much the same way as d.c. generators operate in parallel for high currents and in series for high voltages. Such a compressor arrangement, however, requires fairly complex "cross-over" ducts and valves, which become of prohibitive size and expense for volume flows measured in millions of cubic feet per minute and were, therefore, considered by Westinghouse to be unsuitable for the P.W.T. main compressor system. It is also difficult to choose a compressor design that adequately fits all the various operating conditions of a series-parallel system.

The considerations briefly discussed in the preceding paragraphs, therefore, influenced Westinghouse engineers in their choice of compressor configuration and method of volume-flow variation. These considerations arise principally from tunnel requirements and aerodynamic testing objectives.

Drive Selection

Other important design decisions resulted from application studies on the electric drive for the compressor. These decisions affected both electrical machinery and compressor design. From the tunnel and test section considerations mentioned earlier came the flow, pressure-ratio, and pressure-level requirements. These influenced the tip diameter and hub diameter (these two together determined the cross-sectional area of the airflow passage through the compressor) and, in turn, the tip speed, which determined the speed of the drive. Constant speed having been chosen for aerodynamic as well as electrical reasons, it was then necessary to choose a suitable synchronous speed so as to approach the optimum blade height, hub ratio, and tip speed without the use of large gears. Gears of 216,000-hp. capacity are difficult to obtain and expensive. The drive speed selected was 600 r.p.m.

The A.E.D.C. system power-factor limitations and specification requirements dictated approximately 90 per cent power factor during starting, and unity power factor while running. This indicated that a maximum amount of drive capacity be in synchronous motors, to avoid large capital outlays for power-factor correcting equipment. Of course, synchronous motors cannot be made self-starting and meet the inrush limitations, so they must have separate starting motors or be started from a variable-frequency bus. Also important to remember is the fact that the maximum air-horsepower demand of the 18-stage supersonic compressor configuration under starting conditions is approximately 100,000 hp. at full speed (600 r.p.m.), and the combined inertia of the drive and compressors is 84,000,000 lbs. ft.^{2}. While this inertia is not so great as that of some of the largest waterwheel generators, the stored energy of the system at full speed will be the greatest of any rotating machine ever built. The energy stored in this rotating mass at 600 r.p.m. is 9.35 million hp.-sec. or 1,940 kwh.

Electrical engineers frequently compare large motor or generator installations on the basis of the amount of the stored energy per kva. of rated capacity. This is called the "H" constant, and for the P.W.T. is a little over 40 kw.-sec. per kva.—considered large as electrical machines go.

Thus, considering the horsepower demand of the driven load, the inertia and stored energy of the rotating mass, together with the specified duty cycle (eight 45-min. runs, four 90-min. runs, or one 4-hour run in an 8-hour shift), it appeared that the drive and compressor configuration shown in Fig. 2 would best fit this application.

Starting the Drive

Motors M2 and M3 are 10-pole, wound-rotor induction motors rated 25,000 hp. at 600 r.p.m. or 30,000 hp. at 720 r.p.m. (10-pole synchronous speed). They are designed mechanically for operation at 600 r.p.m. (16 per cent slip) with suitable allowance for overspeed; however, they will never be allowed to operate above approximately 660 r.p.m. Electrically, the motors are capable of developing 210 per cent of their rated 600-r.p.m. torque to accelerate the rotating mass of the largest configuration (WK^2 = 84 million lb. ft.^{2}) in approximately 7 min. from rest to 600 r.p.m. They are then called upon to supply the 600-r.p.m. demand of the compressor (operating at reduced tunnel density or pressure level), while the synchronous machines (M1 and M4) are synchronized with the A.E.D.C. system, after which their large (36-in. electrode) liquid rheostats are operated to reduce their available 600-r.p.m. torque, and thus cause them to share the mechanical load with the synchronous machines. After the drive motors, including the synchronous motors, are all running, tunnel density (pressure) can be increased

from its starting value of 75 lbs. per sq. ft. absolute to its desired operating value (depending on the altitude to be simulated in the test section or the Reynolds Number desired, or both).

Increasing or decreasing the tunnel pressure is accomplished by bleeding air in from high-pressure storage or by pumping it out through a large cross connection to the compressor system of an adjacent facility.

Stopping the Drive

At the end of a run, the tunnel density can again be decreased, the mechanical load transferred to the wound-rotor machines and the synchronous motors disconnected from the line, after which the wound-rotor machines can be decelerated by increasing their secondary resistance (raising the liquid rheostat electrodes). When this has been accomplished, the wound-rotor motors are disconnected from the line and d.c. excitation applied to their stator circuits from a special 400-kw. dynamic-braking exciter. The inertia of the rotating mass then acts to generate a.c. electrical power in the rotor circuits of the wound-rotor machines, which is dissipated as heat in the liquid-rheostat electrode cells and carried away in the electrolyte coolers by the cooling water flowing to the A.E.D.C. reservoir.

The dynamic-braking effect decreases to a negligible value at low rotative speeds because the rotor conductors are then cutting flux only at a very low speed and generating very little power (absorbing very little braking torque). Hence, a mechanical braking system is automatically applied at 45 r.p.m. after the dynamic-braking excitation has been automatically shut off by a speed sensitive switch. This brings the drive quickly to rest.

Control of the Tunnel Drive

A total of ten different operating "configurations" of drive and compressor machinery have been provided in planning the electrical controls and mechanical features of the P.W.T. system. These configurations differ from one another in the number of main motors and compressors selected to run (see Table 1).

Note that configurations 1 and 9 can absorb the full 216,000 s.hp. capacity of the drive, as can configurations 2, 3, and 4. In other words, the full 216,000 hp. can be absorbed in only one compressor (configuration 9), as well as in four compressors (configuration 4).

The operator can select the configuration by setting a multiposition switch on the main duplex control board. This sets up interlocking and auxiliary relay groups, which must be satisfied before the main motors can be started. (The auxiliaries can also be started individually by selecting *manual* instead of *automatic* auxiliary start circuits.) By operating other switches and buttons, the operator can then start, bring up to speed, and load the motors.

Table 1
The Ten Possible Operating Configurations for Drive and Compressors

Supersonic Configurations
1—M1, M2, M3, and M4 driving C2
2—M1, M2, M3, and M4 driving C2 and C3
3—M1, M2, M3, and M4 driving C2, C3, and C4
4—M1, M2, M3, and M4 driving C2, C3, C4, and C5
5—M3 and M4 driving C2
6—M3 and M4 driving C2 and C3
7—M3 and M4 driving C2, C3, and C4
8—M3 and M4 driving C2, C3, C4, and C5
Transonic Configurations
9—M1, M2, M3, and M4 driving C1
10—M1 and M2 driving C1

In addition to the controls needed for starting and stopping, many visual signals and readings are presented on the duplex board to bring both normal and abnormal conditions to the operator's attention. Annunciators and alarms are provided for vital points throughout the system. Temperatures at some 40 different points are recorded. Instantaneous power and power rate-of-change are recorded and retransmitted to the main A.E.D.C. substation and to the main transonic and supersonic aerodynamic control stations.

Control of Auxiliaries

For the more important and complicated auxiliaries (such as the iris valves), complete "fault-finding" panels are located in the auxiliary machinery room adjacent to the supersonic-compressor foundation. The duplex control board has, for each iris valve, only a control switch and four indicating lights, which are labeled *closed*, *closing*, *opening*, and *open*. The transition indications of *opening* and *closing* are desirable because several minutes are required for the iris valve leaves to travel from closed to open, or vice versa, and in transition the operator might obtain a false impression from only two lights. Since there are 24 leaves in each iris valve, each weighing several tons, each leaf is provided with a separate hydraulic operator, and the leaves are moved in unison in two groups of twelve. In the event the operator observes that an indicating lamp has not changed to an *open* or *closed* signal after the normal operating time has elapsed, he may check the fault-finder panel in the compressor auxiliary room to learn the exact cause of trouble; he can then operate a faulty leaf individually by manual control, if necessary. The system is completely interlocked so that the drive cannot be started unless all iris valves and all their components are in the position called for by the *configuration setup* switch.

Similar but smaller local control and instrument boards are provided in the compressor auxiliary rooms for the bearing lubricating-oil systems, bearing-lift oil system (all 22 bearings have oil lift provisions to reduce break away torque), the bearing and shaft dry-sealing air systems, the remote disconnect-coupling hydraulic systems, etc. For the motor lubricating-oil auxiliaries, instrumentation is provided adjacent to each bearing pedestal.

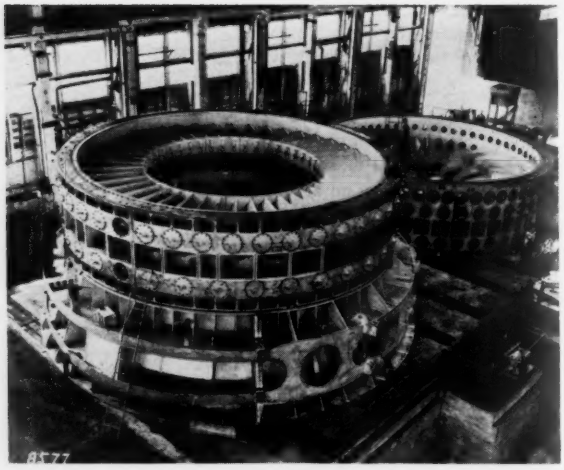

FIG. 3. Stator for transonic compressor being assembled in shop. A 2-hp. gear motor drives each row of blades through a continuous 360-deg. shafting system. Gearboxes that operate linkages controlling position of individual blades are shown between rows of blade housings. There is a gearbox for each blade.

FIG. 4. Closeup of section of transonic compressor showing controllable stator blades.

AUXILIARY POWER

Two 1,000-kva. indoor power centers in the motor building provide 440-volt power to three control centers housing smaller auxiliary motor starters. The heavier breakers for motor cooling fans, exciter drive motors, etc., are housed in the power centers proper. Two of these control centers serve the supersonic auxiliaries, and the third serves the transonic auxiliaries. The control centers also contain 440/110-volt distribution transformers for 110-volt control power.

STANDBY POWER

A third power center, standing physically between the two mentioned above but not normally connected to them electrically, contains starters and breakers for cranes, building lighting, and other services needed for service with main power off. It is served from a different source than the other two and can act as a standby of limited capacity when the two 1,000-kva. auxiliary transformers are disconnected from their normal source.

EMERGENCY POWER

In the event main power is interrupted when the main drive and compressors are running, their large rotating mass would continue to roll for as long as 50 min. (under low tunnel density conditions). This requires that some provision be made for lubricating bearings, energizing mechanical brakes, and other vital auxiliaries during this interval. This is especially true of the compressor bearings, which require excess oil to be circulated, in addition to that required for lubrication, simply to carry away heat transmitted from the working air and hot parts of the compressor, which reach 650°F. and higher. Therefore, a 300-kw. diesel-engine generator set has been installed to power these vital auxiliaries (principally lubricating oil pumps), while the compressor and drive coast to a low speed.

COMPRESSOR INSTRUMENTATION

The controllable stator blades of the compressors are driven by 440-volt, three-phase reversing motors controlled manually by remote switches located in the transonic and supersonic aerodynamic control stations. Blade position is indicated by Synchrotie transmitters and indicating receivers at the same control stations.

Compressor inlet, outlet, and interstage pressures and temperatures are read and averaged at several stations in each compressor. These readings appear on sets of instruments at the aerodynamic control station adjacent to the blade position indicators. Compressor stall warning is also provided by high-response pressure pickups, which actuate an alarm and indicator at the main control station.

Mechanical instrumentation to read shaft and bearing vibration, axial spindle position, and blade tip clearance is also provided on each compressor and indicated or recorded at the aerodynamic control stations. Provision is made for using the vibration pickups in conjunction with a sine-wave generator and HQ balancing set during the initial balancing of the compressors.

APPENDIX (I)—UNUSUAL STATISTICS

(1) Inertia of the rotating system—84,000,000 lbs. ft.^{2}.

(2) Stored energy in shaft when operating at 600 r.p.m.—9,350,000 hp.-sec.

(3) Length of longest shaft in drive system—45 ft.

(4) Length of entire rotating system—575 ft.

(5) Airflow past a given point—13,000,000 cu.ft. per min.

(6) Transonic rotor—forged-steel blades, 2 ft. wide and 6 ft. long, weigh 1,200 lbs. each. These blades are mounted on discs 18 ft. in diameter. Centrifugal force tending to pull each blade from its roots is 800 tons.

(7) Liquid rheostats—heat dissipation capacity of 25,000 kw. each. Electrodes are 3 ft. in diameter.

Appendix (II)—Engineering Highlights

Some of the new engineering developments resulting from design and construction of the compressor and drive system for the Propulsion Wind Tunnel are:

(1) Development of new techniques for using low-speed model data in achieving full-scale design. (A $^1/_{18}$-scale low-speed model was built by Westinghouse and used to gather data for the full-scale model.)

(2) Stator-blade control used for volume regulation of large multistage axial-flow compressors.

(3) Application of detuning techniques for preventing dangerous resonant frequencies in large forged-steel rotor blades. Detuning has been applied previously to turbines and to small compressors but never to a compressor system of this magnitude. For the Propulsion Wind Tunnel compressor rotors, the distribution of blade thickness and disc profile were selected to set their natural frequencies above lower multiples of the compressor operating speed.

(4) Development of large remotely operated flexible disconnect couplings.

(5) Design and application of huge iris valves (approximately 35 ft. in diameter).

(6) Design and manufacture of the most powerful electric motors ever built (83,000-hp. synchronous motors). The largest motors previously built were 65,000-hp. pump motors for Grand Coulee Dam.

(7) Design and manufacture of largest liquid rheostats ever built.

Appendix (III)—Sequence of Operations for Starting

Suppose tunnel conditions require all four motors to drive compressors C2 and C3. The operator must:

(a) Select configuration 2 on the *setup* switch. Select automatic auxiliary start operation on *auxiliary setup* switch.

(b) Push *auxiliaries* single-start button that starts all lubricating oil pumps, lift pumps, dry-sealing air blowers, iris valves, hydraulic pumps, etc., required for bearings 5 through 18 inclusive, and all other auxiliaries required for proper operation of configuration 2.

(c) Open remote disconnect coupling RC-2, breaking the supersonic compressor shaft between C3 and C4.

(d) Set first iris valve to direct air into C3 from C2 and not into the by-pass duct.

(e) Set second iris valve to direct air from C3 into the by-pass duct and not into C4.

(f) Stop turning gear (if running). (This is optional as turning gear is overriding.)

(g) Make sure that manual flexible disconnect coupling between drive and transonic compressor is broken and other couplings are properly connected.

(h) When all necessary auxiliaries are running, a *drive-ready* light glows. If the test-crew supervisor is satisfied that the tunnel and compressor are in readiness, the main drive can be started by pushing one button at the main duplex control board.

Fig. 5. Inserting rotor into stator of one 83,000-hp. motor. End of rotor shaft is carefully positioned against shaft end of adjoining 25,000-hp. motor. When the shafts were connected, the stator was moved to the right until it was in position.

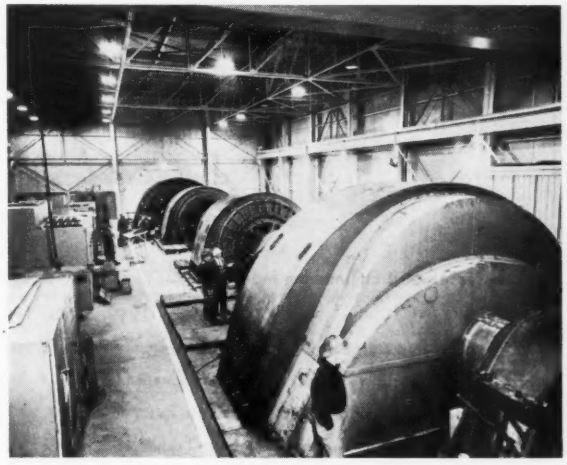

Fig. 6. The four drive motors in the partially completed tunnel facility. The two in the center are 25,000-hp. wound-rotor motors; those on the ends are 83,000-hp. synchronous motors.

(i) The liquid rheostats are automatically controlled to hold the starting inrush at 20,000 kva. during the first 40 sec. after M2 main breakers are closed; then M3 main breakers are closed and the inrush is similarly controlled; then the drive is automatically accelerated to the speed preselected by the operator (600 r.p.m.).

(j) The speed selector dial is set to 600 and the motors are accelerated at 210 per cent torque under the influence of the automatic power-rate controllers, which hold their combined rate of power increase to 30,000 kva. per min. Additional regulator-sensing elements prevent exceeding current limits, keep load balanced, and provide velocity feedback and fine speed matching as the drive approaches the preselected speed.

(k) The voltage of the incoming synchronous motors is regulated to match line voltage, and, when slip frequency, phase relationship, and voltage are satisfactory, the synchronous motor most remote from the load is connected to the line (M1 in this case).

(l) Again, the regulators operate to raise the liquid-rheostat electrodes and thus cause the wound-rotor machines to develop less torque at the existing speed (600 r.p.m.). This, in turn, transfers load to the synchronous motor M1, which "twists" the drive shaft between M1 and the connected load an amount proportional to the driving torque being developed by M1.

(m) If it were not for special provisions in the manual disconnect coupling, this twist would prevent the large synchronous motors (M1 and M4) from properly sharing the load. When making up that coupling, however, the operator "off set" it in such a way as to counteract this shaft twist, so that, as load is increased on M1, M4 is brought into correct phase relationship with the bus, and its breaker is automatically closed. The operator sees an indication of this by observing the Synchroscope of motor M4, whose pointer is standing still a few degrees ahead of 12 o'clock after M1 is on the line and then gradually moves exactly to 12 o'clock as load is transferred to M1 by unloading the wound-rotor machines.

(n) When both synchronous machines are on the line, the main aerodynamic control station is notified and tunnel density can be increased. The load regulators see to it that the resulting additional load is taken by the synchronous machines until they are 95 per cent loaded, after which the wound-rotor machines take the remainder until they are fully loaded; then the synchronous machines take the last 5 per cent of their capacity if the driven load requires it. This pattern can be altered at will by the operator making simple adjustments. Holding 5 per cent of the synchronous capacity in reserve merely ensures that small, sudden increases in load below the full installed capacity will be taken by the synchronous machines within their rating, rather than at overload, and also tends to reduce the reactive kva. swings.

The above operations require about 8 min.

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These may be obtained by writing to

Publications Department, Institute of the Aeronautical Sciences, Inc., 2 E. 64th St., New York 21, N.Y.

IAS Honors Night Dinner Address

(*Continued from page 51*)

our scientific environment will make of man, for an environment effects the form and thought of each new generation. To date, the results of science have been primarily materialistic. We have measured success by our products rather than by ourselves. A materialism that overemphasizes short-term survival detracts from the humanism essential to long-term survival. We must remember that it was not the outer grandeur of the Roman but the inner simplicity of the Christian that lived on through the ages.

"I have stated a problem. You have the right to ask for a solution. I believe the solution lies in each individual, through the standards he holds; that it lies not in political parties or radical movements, but in human values and gradual trends; not in a greater complication, but in a greater simplicity of life. In other words, I believe that the solution lies within ourselves and that we can find it nowhere else. Our parties, movements, laws, and codes are important, but they are only outward manifestations of our inward values. The excessive materialism of the modern world is a reflection of the excessive materialism in modern man. Nothing is gained by attacking the reflection; we must concentrate on the source; and in doing so, we can be successful only by bringing to our assistance the factors of trend, faith, and time.

"Unexpanded by the time dimension, flattened on a momentary, mental screen, the chaos of our modern world is staggering. We watch assemblies and conferences bog down until we realize that man has not the wisdom to solve his problems by any sweeping, detailed plan. But when we add the scope of time and release in it the catalyst of faith, the future clarifies, and we see that, within the bounds of natural law, man's destiny is shaped by man's desire. We desired a mechanistic civilization; that set the trend, and we achieved one. To achieve a civilization based on human values requires the desire within ourselves. If we actually have that desire, our scientific, industrial, and military forces will fall, automatically, into line behind it, supporting with material strength the human qualities essential to overall power and permanent survival.

"But we must have more than an intellectual desire filed away in the archives of idea. It must enter the roots of our being until it shapes our action instinctively, as well as through the conscious mind, until we see the producer as more important than his product, and find it no sacrifice to renounce material standards of success—until we realize in our bones, as well as in our brains, that the character of man still forms the essential core of a lasting civilization."

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Corporate Member News

• **Air Associates, Incorporated . . .** The Air Research and Development Command, USAF, has announced that a multifrequency portable UHF communications set, AN/PRC-14, is being produced in quantity by Air Associates. Designed primarily for ground-to-air use, this new electronic product is but half as heavy as presently used sets and has a greater range. The set measures 8 by 10 by 2.75 in. and is carried about by means of a conventional infantry man's shoulder harness. The antenna is attached to the top of a steel helmet. The communications set was developed by the Electronic Research Laboratories at Rome Air Development Center, Griffiss AFB, N.Y., and by Air Associates's Electronic Equipment Division.

• **Aircraft Radio Corporation . . .** An inverted "L" antenna, broadbanded to cover 118–148 mc., with a vertical section of 8 in. and a horizontal section of 13 in., has been developed. This VHF antenna, designated A-15, may be single-hole mounted on the undersurface of the smallest two-place helicopter. The company states that it has been designed to withstand mild icing and may be used on aircraft that can fly at 250 m.p.h.

• **American Bosch Corporation . . .** A new branch plant of approximately 100,000 sq.ft. is now under construction in Columbus, Miss., and is scheduled for completion this coming April 1.

• **Bell Aircraft Corporation . . .** On December 12, Major Charles E. Yeager, USAF, flew the Air Force Bell X-1A at a speed of more than 1,600 m.p.h. above Edwards AFB, Calif. To make this flight, the X-1A was carried aloft in the bomb bay of a specially modified Boeing B-29. The X-1A, the fifth article in the X-1 series of planes built by Bell for the Air Force, is covered with a polished duraluminum and is unpainted save for the under part of the wings and the ventral fin which are painted white to aid visual tracking. The X-1A, which is of conventional straight-wing configuration, is 35 ft. 7 in. long and 10 ft. 8 in. high and has a wing span of 28 ft. Fully fueled for launching, it weighs over 16,000 lbs. This research plane is powered by a liquid-propellant rocket engine, built by Reaction Motors, Inc. The engine develops 6,000 lbs. of thrust by virtue of four 1,500-lb.-thrust rockets that comprise the engine assembly and which may be fired either singly or in concert. Under full power, the X-1A has a flight endurance of approximately 4.2 min.

• **Boeing Airplane Company . . .** A company release listed the following nine items as highlighting its 1953 activities: (1) designation of the Wichita Division by the USAF as a second source of the Boeing B-52 Stratofortress production; (2) continued on-schedule production by the Wichita Division of B-47 Stratojets and KC-97 Stratofreighters by the Seattle Division; (3) the Bomarc pilotless interceptor program; (4) construction progress of the nation's first jet transport prototype; (5) new models in both the B-47 and C-97 series; (6) successful tests with the world's first experimental jet tanker; (7) the announcement of a forthcoming turboprop version of the C-97; (8) delivery of the last of its propeller-driven bombers, thus making Boeing bomber production strictly jet; and (9) numerous record and outstanding performances by Boeing planes.

• **Canadair Limited . . .** It was recently reported that a maritime reconnaissance version of the four-engined Britannia will be built by Canadair under license from Bristol Aeroplane Company, Ltd., England. The date for initiating Britannia production has not been announced.

• **Chance Vought Aircraft, Inc. . . .** Frederick O. Detweiler has been elected President of the newly formed, wholly owned subsidiary of United Aircraft Corporation. Mr. Detweiler was formerly the manager of Chance Vought Aircraft Division. For details of the change-over from a division to a subsidiary of United Aircraft, please refer to the United Aircraft item in the Corporate Member News of the February AERONAUTICAL ENGINEERING REVIEW.

• **Consolidated Vultee Aircraft Corporation . . .** An order has been received by Convair to convert an undisclosed number of RB-36 reconnaissance bombers into carriers for Republic Aviation Corporation's RF-84F reconnaissance fighters. An RB-36 so modified is able to take off with a "parasite" RF-84F attached to the under part of the bomber's fuselage and, once airborne, to release and retrieve the fighter while in flight. The development work on this RB-36-RF-84 combination, known as "Project Ficon," began in 1950. Tests on this air-launching technique were conducted by the personnel of the USAF Air Research and Development Command, Republic, and Convair. The original RB-36-RF-84 Ficon combination is currently undergoing additional developmental testing at Convair's Fort Worth Division. . . . The lastest version of the Convair's USAF bombardier trainer, the T-29D Flying Classroom, is equipped with camera-scoring units and other classified electronic gear. It has stations for seven students and instructors. The T-29D is one of three USAF planes developed from the same design. The others are the T-29C navigator-bombardier trainer, containing stations for 14 students and instructors, and the C-131A Flying Samaritan, designed to carry 27 litters or 40 passengers or combination loads.

• **Cornell Aeronautical Laboratory, Inc. . . .** The newly developed hypersonic impulse tunnel, referred to in last month's Corporate Member News, has tested rocket and missile models under stratospheric conditions at speeds of 10,000 m.p.h. The duration of the 10,000-m.p.h. test is approximately 1/1,000 of a second; tests of greater duration would melt the apparatus. The wind tunnel is said to be capable of reaching Mach 20, or about 14,000–15,000 m.p.h. This tunnel, believed to be the fastest of its type in the world, was developed under contract with the USAF's Arnold Engineering Development Center, after the project originated under the laboratory's own funds.

• **Curtiss-Wright Corporation . . .** According to a recent announcement, the Turbo Compound aircraft engine has been given a new and higher military rating of 3,700 hp. At its new 3,700-hp rating, the Turbo Compound is the "most powerful 18-cylinder engine" yet developed, yields 1 hp. for each 0.92 lb. of dry weight, and produces 1 hp. for every 0.91 cu.in. of displacement. This type of engine currently powers the Douglas DC-7 and the Lockheed Super Constellation air-line transports and a series of military aircraft, including the Martin P5M, Lockheed P2V, Fairchild C-119, Lockheed R7V, and Lockheed C-121.

• **Elastic Stop Nut Corporation of America . . .** A recently developed two-lug anchor lock nut is said to be up to 45 per cent lighter than previous designs, to be easier

The X-1A, designed and built by Bell Aircraft Corporation, was flown at a speed of more than 1,600 m.p.h. on December 12. For further details on this rocket-powered research plane, see the Bell item on this page.

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Two power-packed jet engines, *two* "decks" of 52 rockets, *two* men at controls and triggers, up to *two thousand* miles of range... and the comforting assurance of single-engine performance if necessary; that's the Northrop Scorpion F-89. These U. S. Air Force interceptors now stand ready for double-duty defense at far-away bases; they can rise in seconds on first radar alert to intercept air invaders, and they can follow, harrass and destroy them hundreds of miles before they reach target. The long-range Scorpion F-89 is one of many precision products built by Northrop for all branches of the U. S. Department of Defense.

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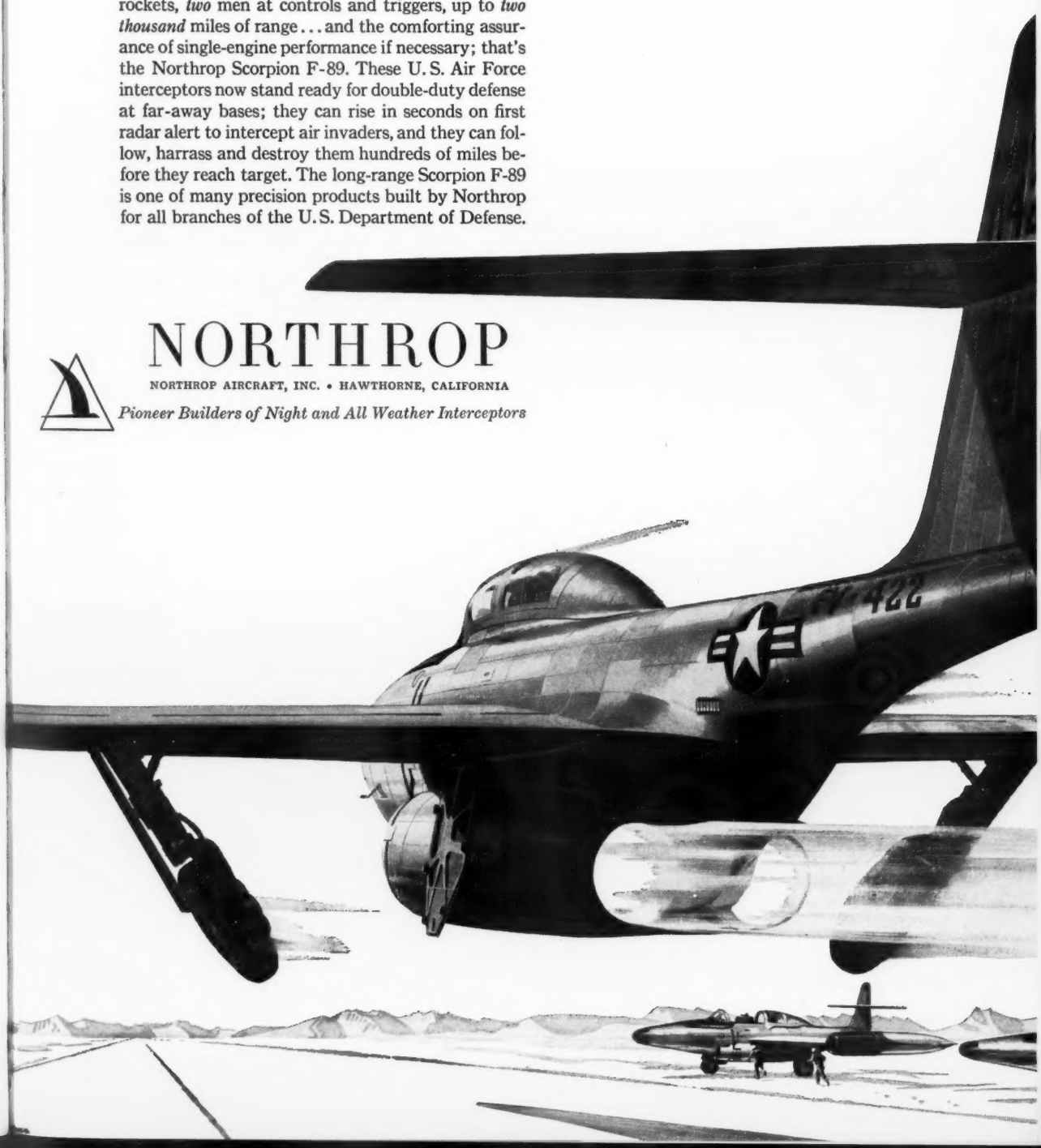

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to weld, and to require up to 75 per cent less critical material. Designed for service up to 1,200° F., the new ESNA ZA1W1200 is available in 8-32, 10-32, and 1/4-28 thread sizes. It can be had with base plates with plain lugs, lugs with projections for welding, or lugs with holes for riveting. The new ZA1W1200 is functionally and dimensionally interchangeable with ESNA ZA1-1200 nuts. . . . A new and improved AISI 420 corrosion-resistant steel "Rollpin" is now available, according to a recent company release. This "Rollpin," capable of withstanding a 100-hour salt-spray test, meets the requirements of AMS 7207.

• **Flight Refueling, Inc.** . . . The company's permanent mailing address is now Post Office Box 1701, Baltimore 3, Md. General Offices and Engineering are temporarily located at 930 East 22nd St., Baltimore. Telephone: Hopkins 7-9200. TWX No. BA99. The permanent location of these offices will be established at Friendship International Airport, Baltimore, when facilities now under construction there are completed in mid-1954. Manufacturing, Quality Control, and Purchasing will remain at the Municipal Airport, Danbury, Conn., until further notice. The phone is Danbury 8-5611.

• **Flight Safety Foundation, Inc.** . . . At the recently held Annual Meeting of the Board of Governors, J. Carlton Ward, Jr., MIAS, President, Vitro Manufacturing Company, was elected Chairman. At the same time, Rear Adm. Luis de Florez, USN (Ret.), FIAS Chairman of the Board, The de Florez Company, Inc., was appointed to the Executive Committee, succeeding Lt. Gen. Elwood R. Quesada, USAF(Ret.), now with Lockheed Aircraft Corporation as Vice-President and General Manager of the new Missile Systems Division. General Quesada continues on Flight Safety Foundation's Board of Governors.

• **General Electric Company** . . . It was announced on December 22 that initial tests had been conducted at the new $1,000,000 addition to G-E's plant near Johnson City, N.Y. This new facility is being used for environmental controlled testing of aircraft armament systems built by the company for USAF bombers.

• **Jack & Heintz, Inc.** . . . A manufacturing safety award for 1953, sponsored by the Industrial Commission of Ohio and the Greater Cleveland Safety Council, was presented to Jack & Heintz for "the best continuous production record without accident in the six-month period beginning April 1 and ending September 30."

• **The M. W. Kellogg Company** . . . A 16-page "Buyers Guide" lists sources of "Kel-F" polymer materials, finished products, as well as application services offered by more than 75 U.S. and Canadian companies. This newly issued booklet is available without charge from the Technical Service of Kellogg's Chemical Manufacturing Division.

• **Lockheed Aircraft Corporation** . . . The mechanized final assembly line for T-33 jet trainers, recently installed at Lockheed's Van Nuys, Calif., plant for approximately $60,000, has enabled some 3,000 man-hours per month to be lopped off the production time. This continuously

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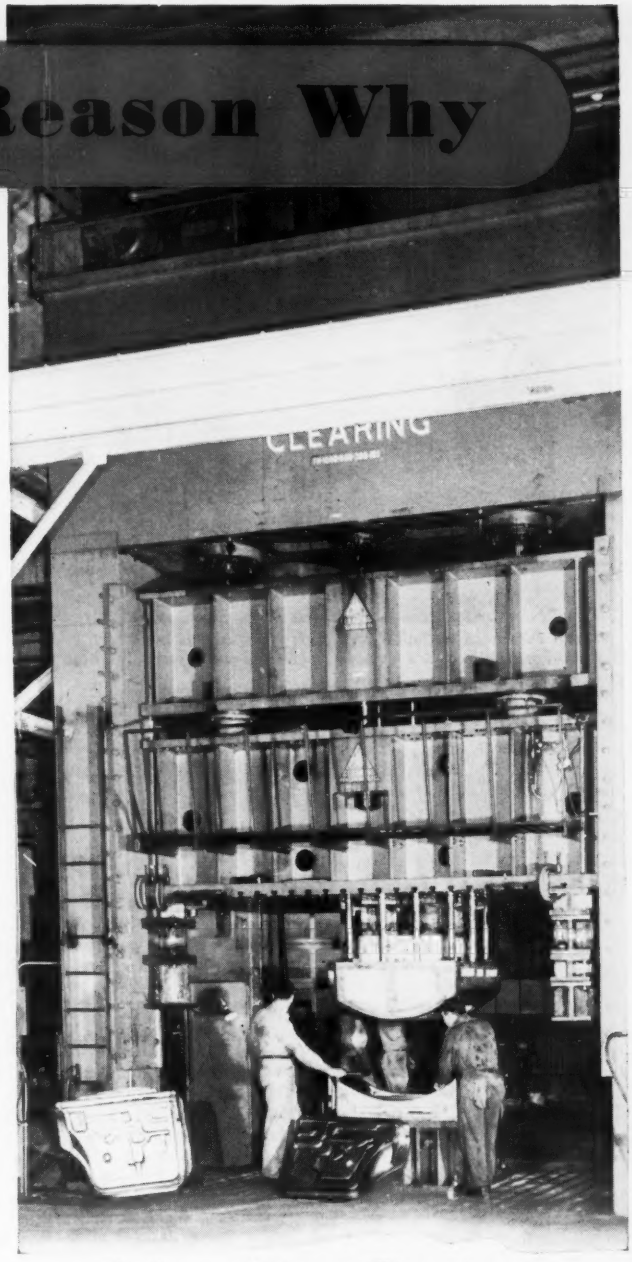

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PLANT 2
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PLANT 3
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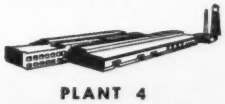

PLANT 4
Hillsdale, Mich.

North American Aviation, Inc., has designed this two-place trainer version of the F-86 Sabre. For details of this transonic trainer, please refer to the North American item on this page.

moving line is U-shaped, has an overall length of 725 ft., and has 22 separate assembly stations.

• **McDonnell Aircraft Corporation . . .** The first of an entirely new series of carrier-based fighters, the all-weather single-jet F3H-1N Demon, has been delivered to the U.S. Navy. The thin wings and tail surfaces are swept back sharply. The wings have a span of 35 ft. 4 in. and can be folded for compact stowage aboard aircraft carriers. The fighter is over 59 ft. long and has a height of almost 14 ft. It is powered at present with a single Westinghouse J-40 turbojet engine; however, the Demon will be equipped with the Allison J-71 power plant when these engines become available. The armament consists of fast-firing high-velocity 20-mm. cannon and multiple combinations of external stores, including a large number of air-to-air rockets. . . . Robert H. Charles, a Director and a member of the Executive Committee, has been appointed Executive Vice-President.

• **Meletron Corporation . . .** Production, interrupted by a fire on December 29 that severely damaged Meletron Plant No. 1, was recommenced on a limited basis within 9 days after the crippling fire. Salvage and new construction operations were begun on the damaged building on January 6. It was expected that the offices of the corporation, temporarily located at 6767 Romaine St., Hollywood, Calif., would be returned to the rebuilt plant at 950 N. Highland Ave., Los Angeles, 45 days later.

• **Minneapolis-Honeywell Regulator Company . . .** The recently announced MG13A Actuator is said to meet the military aircraft requirements of MIL-E-5272, AN-E-19, MIL-A-5906, and MIL-E-7894. This new unit, which weighs 1 lb. 14 oz., consists of two-phase reversible induction motor, a velocity signal generator, and a 50-to-1 gear train. The unit has a diameter of $2^{9}/_{16}$ in. and a length of 5 in. . . . Charles B. Sweatt, who has been Executive Vice-President since 1945, was recently elected to the newly created post of Vice-Chairman of the Board of Minneapolis-Honeywell. At the same time, two former Vice-Presidents, Tom McDonald and A. M. Wilson, were made Executive Vice-Presidents.

• **North American Aviation, Inc. . . .** A two-place trainer version of the F-86F Sabre is now undergoing flight evaluation by the corporation's Engineering Flight Test Section. It is designed for advanced pilot training in high-speed flight, gunnery, and dive bombing. In building the trainer, North American engineers added a tandem cockpit, dual controls, and a duplicate instrument panel to the original installations of the F-86F. Only two modifications of the F-86F's airframe were necessary to compensate for the additions: the fuselage section between the nose and wing roots was extended 63 in., and the 35° sweptback wings were moved forward 8 in. The trainer prototype is powered with a General Electric J-47-GE-27 turbojet engine. The trainer has retained most of the performance characteristics of the original F-86F; it is rated in the 650 m.p.h. class, has a maximum service ceiling of 45,000 ft., and has a combat radius of over 600 statute miles. Provision has been made for installation of two 0.50-cal. machine guns for gunnery practice. The trainer version has retained the "all flying tail," the APG-30 radar set, and the A-4 gunsight. . . . An undisclosed number of FJ-4 carrier-based jet fighters will be produced by North American's Columbus Division for the U.S. Navy. The FJ-4's are to be powered by Curtiss-Wright J-65 Sapphires.

• **Northrop Aircraft, Inc. . . .** An office has been opened at Ogden, Utah, for liaison with USAF activities centered at Hill AFB. L. H. Coates is the Manager of Northrop's Ogden office.

• **The Parker Appliance Company . . .** Catalog No. 4370, now available on request from Parker's Cleveland office, presents a new line of socket-type Weld-lok tube fittings for permanently welded joints. These Weld-lok tube fittings come in steel or stainless steel for all commonly needed body shapes. Sizes range from $^{1}/_{4}$-in. through 2-in. outside diameter. This new line includes unions, adapters, connectors, tees, crosses, gage connectors, and elbows.

• **Piasecki Helicopter Corporation . . .** It was recently announced that a program has been reactivated to have the YH-16 Transporter certificated for commercial use by the CAA.

• **Republic Aviation Corporation . . .** The Board of Directors recently elected Walter G. Bain a Vice-President of the corporation. Mr. Bain was previously Executive Assistant to Mundy Peale, AMIAS, President of Republic Aviation . . . . William H. Moore has been elected to the corporation's Board of Directors. Mr. Moore is Vice-President of Bankers Trust Company.

• **Solar Aircraft Company . . .** A European Division of Solar Aircraft was recently formed, with W. E. P. Johnson as Manager. Mr. Johnson, a British pioneer in the development of gas-turbine engines, has his headquarters in London, where Solar has opened an office. Mr. Johnson's territory covers Free Europe. His duties include licensing European firms to use Solar designs and processes, sale of Solar products, interchange of technical information, and obtaining European patents for use by Solar in the United States.

• **Sperry Gyroscope Company, Division of The Sperry Corporation . . .** A facility has been added in Cleveland for the purpose of expanding sales and servicing of aviation equipment in the Great Lakes area. This addition is a one-story building located at 3807 W. 150th St., Cleveland.

• **Stratos Division, Fairchild Engine and Airplane Corporation . . .** An evaporative refrigeration system that combines an air-cycle refrigeration system with a water evaporator and conventional air-to-air heat exchangers has been built by Stratos for the X-3 research aircraft. The X-3, built by Douglas Aircraft Company, Inc., under joint USAF-USN-NACA sponsorship, uses air bled from its jet engines for pressurization and cooling. The bleed air is first passed through a ram air heat exchanger and a blower heat exchanger. The cabin air is next passed through an open-cycle evaporative cooler in which the water is boiled away at temperatures substantially under water's sea-level boiling point and well below the effective temperature of the air immediately surrounding the aircraft. The temperature is further reduced in an air-cycle refrigeration turbine before entering the cockpit. This Stratos-designed refrigeration system is said to constitute the first aircraft application of evaporative cooling.

• **United Air Lines, Inc., and Curtiss-Wright Corporation . . .** The first of four electronic simulators, designed and built by Curtiss-Wright, has been delivered to United Air Lines. The one already de-

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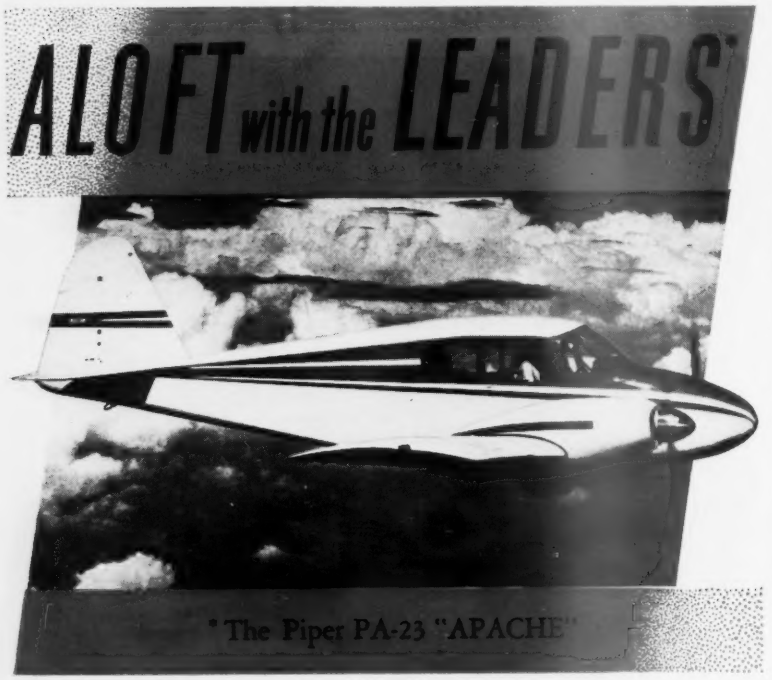

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• **Westinghouse Electric Corporation** . . . On February 2, 15 employees of Westinghouse began a special 16-month course at The Harvard Graduate School of Business Administration, leading to Master of Business Administration degrees. During this period of study, the 15 men will receive their regular salaries from the company as well as their tuition and fees and such other expenses as travel and books. If the company's experience with this Graduate Business Administration Course is favorable, continuance of the Westinghouse program will be considered in future years.

IAS Sections

Chicago Section

Leland W. Sims, *Secretary*

On December 17, the Chicago Section celebrated the Fiftieth Anniversary of Powered Flight by honoring aviation pioneers. Two hundred and seventy-five members and guests attended the reception, social hour, and dinner in the Grand Ballroom of the Sheraton Hotel in Chicago where 26 famous and distinguished aviation personalities were guests of the Section at the speakers' table. These included Herbert W. Anderson, George J. Behl, Edwin G. Bracher, John L. Carr, John A. Casey, Lewis M. Churbuck, Ralph J. Hall, Brig. Gen. John P. Henebry, Carl V. Johnson, Col. Reed G. Landis, Louis A. Leverone, Capt. Benjamin Lipsner, Joseph K. McLaughlin, William B. Miller, Jr., A. C. Moore, Brig. Gen. Wilson V. Newhall, Col. Frank E. Quin-

dry, Joseph F. Read, Vice Adm. Charles E. Rosendahl, USN, Clarence N. Sayen, Howard L. Scamehorn, Roscoe Turner, Brig. Gen. Lafeton Whitney, and S. J. Wittman.

The reception and social hour was opened at 6:45 p.m., and dinner was served at 8:00 p.m. The social hour was sponsored by the American Phenolic Corporation, Aircraft Engine Division-Ford Motor Company, and Air Associates, Incorporated. The meeting was opened by Chairman Alfred F. Stott, Dean of Engineering, Aeronautical University, at 9:00 p.m. Mr. Stott welcomed all present to the most elaborate meeting ever held by the Chicago Section. He, at this time, thanked the Program Committee Chairman, Charles L. Bonnette, and his committee for their efforts in making the program possible. Special credit was given to Kenneth L. Burroughs, President of the Aeronautical University; Norbert C. Schnaubelt, Robert Saff, Benedict Vinicky, and Harold Wackelin, all of Globe Corporation's Aircraft Division; Theodore Linnert and Carl Eck, of the Airline Pilots Association; and Orland J. Engle, of R. R. Donnelly Company, for their efforts, which lasted most of the summer, in making plans for this meeting.

Chairman Stott then introduced the Toastmaster for the evening, Dr. D. P. Barnard, Research Coordinator, Standard Oil Company of Indiana. Dr. Barnard introduced the guests, giving a brief historical background of each with particular emphasis on his contribution to the field of aviation. Dr. Barnard then introduced Louis A. Leverone, President of Nationwide Food Services, who has acted this past year as Chairman of the Governor's Committee for the Fiftieth Anniversary of Powered Flight. Mr. Leverone also represented Governor Stratton, who was unable to attend. He spoke briefly of the year's activities in the commemoration of the Wright Brothers flight and expressed the regrets of the Governor for missing the event.

Dr. Barnard then introduced the guest of honor and speaker, Ralph S. Damon, President, Trans World Airlines, Inc., whose address was titled "Aviation's Next Fifty Years." Mr. Damon described the accomplishments of the last fifty years, not only in the field of aviation, but in automotive, radio, television, and atomic fields of endeavor. When speaking of the accomplishments of the Wright Brothers, Mr. Damon emphasized the careful preparations that they made and said that their work, though seemingly crude now, was actually carried out in an extremely studious manner. Many of the basic flying principles that they developed are still in use by modern pilots.

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Although the Wright Brothers gave us the early advantage, the first 25 years after their flight showed other countries in the lead in the advancement of aircraft. World War I spurred development in aviation, but interest again waned until Lindbergh's flight. Half of the past 50 years had then elapsed. Following this, the airlines, the Civil Aeronautics act, and World War II put America back in the lead in both commercial and military aircraft.

As for the future, Mr. Damon predicted the early adoption of the jet transport, but this adoption will be a minor event in the next 50 years, which will see many times more than has been accomplished in the past. The fact that aviation has won an accepted position in everyone's life will accelerate its future advancement. He pointed out that aviation has not matured and will be subject to continued and increasing progress that will never be finalized. The full cooperation of all who are engaged in all related fields of aviation will be necessary, because of the high degree of specialization now existing, for maximum progress in the years ahead.

Chairman Stott then closed the meeting at 10:15 p.m. with expressions of thanks to Mr. Damon and Dr. Barnard.

Hagerstown Section

George W. Westphal
Secretary-Treasurer

The December 8 meeting was called to order by the Chairman at 8:00 p.m. in the Packet Room of the Terrace Restaurant. A letter from the Chairman of the Washington Section, Capt. W. C. Fortune, USN, expressing appreciation for the arrangements for the joint dinner meeting of November 17, was read. Mr. Eisiminger, Chairman of the Program Committee, then reviewed the programs for the first months of 1954, including plans for a proposed field trip to the wind tunnel facility of the Aberdeen Proving Ground on some evening or Saturday in March.

The Chairman then read a financial report by the Secretary-Treasurer, which was approved by the membership as read.

Mr. Eisiminger introduced the speaker of the evening, Robert D. Rhodes, Chief Industrial Engineer of the Fairchild Aircraft Division and a graduate of the Carnegie Institute of Technology and the University of Hawaii.

Mr. Rhodes' subject, "Production Problems on Jet-Type Aircraft," related specifically to production problems experienced by the Fairchild Aircraft Division in producing the wing tips and fin of the B-52. The variety of industrial-engineering problems encountered in setting up production of these B-52 components was amazing. The complexity of the subcontracting structure was brought out, as were some of the difficulties that result therefrom. The relationship between size of parts and producibility was emphasized, the speaker showing how such seemingly unlikely factors as state labor laws become quickly involved as part sizes go up. The undesirability of having to do much forming in the jig was shown, as well as the tendency for this situation to exist early in production.

Throughout his talk, Mr. Rhodes drew interesting comparisons between processes on the B-52 and on the C-119, since these aircraft represent two different ranges of the speed spectrum. The airfoil accuracy-to-contour and smoothness demanded by high speed make the fabrication of such components much more of a problem than the fabrication of corresponding parts on a low-speed airplane. Much more machining is required on the B-52 components; moreover, the required tolerances necessitate a high level of machine-tool maintenance. Older tools, still with adequate accuracy for C-119 components, cannot be used at all on the B-52 parts. The burden of the speed requirement in the B-52 is reflected by the pounds of airplane produced per square foot of factory area during a given period. This figure is 0.8 for the B-52 as compared to 2.0 for the C-119. Mr. Rhodes concluded his talk by answering numerous questions from the floor.

The meeting was adjourned at 10:00 p.m. Attendance was 20.

Hampton Roads Section

John E. Duberg, *Recording Secretary*

On November 17, 1953, the Hampton Roads Section of IAS met at the Morale Activities Building of the NACA. More than 75 members and guests attended. Charles Zimmerman, Assistant Chief of the Stability Research Division of the Langley Laboratory of the NACA spoke on the subject "The Design Problems of Vertically Rising Aircraft" and illustrated his talk with motion pictures of flying scale models.

To make his talk more concrete, Mr. Zimmerman based his discussion on the problems that he encountered in the design of low-aspect-ratio-wing aircraft with wing-tip-mounted propellers, capable of flying over an extremely wide speed range. His first interest in such an aircraft occurred at Langley Field in 1933 when Fred Wiecke wanted to build a private-owner aircraft capable of taking off and landing in small fields. Working with him, Mr. Zimmerman investigated the possibilities of an aircraft with a low-aspect-ratio wing and with wing-tip mounted propellers and found that such an aircraft could be landed easily at steep angles of glide, but that not enough power was available for take-off. The investigation was continued, and a flying model was constructed at Langley in 1934.

In 1937, Mr. Zimmerman joined the staff of the Chance Vought Aircraft Division of United Aircraft Corporation to develop a high-performance fighter capable of very steep landing and take-off. In 1942, a 2,000-lb. airplane, the V-173, was built which had wings of circular plan form with two propellers mounted on wing-tip nacelles. The V-173 could not hover, but it could fly at a maximum angle of attack of 41°. (Work on a larger aircraft, the XF5V-1, was continued until it was cancelled in 1948, when it appeared that its high performance could be exceeded by jet-powered aircraft.)

Problems peculiar to these aircraft include the maintenance of visibility over wide angle changes, the design of a long landing gear to support the aircraft at high angles of attack, and the ability to control over wide attitude changes. Probably the most difficult problem is that of the propeller design, and it may well be that flapping blades are required to reduce blade bending stresses; they were used on the V-173. A particularly difficult design aspect of the XF5V-1 was the gearing to supply power to the wing-tip-mounted propellers.

Los Angeles Section

Evert C. Hokanson, *Secretary*

The Fiftieth Anniversary of Powered Flight was most appropriately commemorated by the Los Angeles Section on December 17. The program, presented by the Historical Branch of the L. A. Section with Jack Canary presiding, had three outstanding highlights.

First, Robert B. Johnston, RAND Corporation Engineer, gave a paper on "The Engineering Development of the Wright Brothers Airplane." Most of us learned for the first time that the Wright Brothers actually used fundamental theories developed by themselves, their contemporaries, and predecessors to construct first man-carrying kites and finally the first airplane to fly under its own power. The work was conducted on a scientific basis, not by the cut-and-try method as most of us had believed. Their patents on wing warping for lateral stability were well enough conceived to cover the later development of movable ailerons. An interesting historical film was shown from the private collection of Historical Associate Edward Maloney. This film included pictures taken of the Wright Brothers flights with the first movie camera developed by Thomas A. Edison. Mr. Maloney gave additional comments of interest about the Wright Brothers accomplishments.

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Second, the authentic full-scale reproduction of the Wright Brothers Airplane was lowered from its place in the ceiling of the auditorium so all of the 400 people attending the meeting could have a close-up view. There were many individual discussions concerning both mechanical and aerodynamic design.

Third, an unexpected treat, and particularly fitting for the occasion, was a film, *We Saw It Happen*, by United Aircraft Corporation. This movie, depicting 50 years of flight, is an outstanding documentary film, dramatically showing the tremendous technical achievements made by our industry. After seeing this film, no one connected with the aviation industry could help but be proud of the part he has played in its growth.

Mr. Canary announced that the Historical group is now making plans in conjunction with the Air Force Association to restore a World War I Sopwith "Snipe" to its original condition. When completed, it will be displayed in the Los Angeles Museum.

The Los Angeles Section Summer Meeting Sub-Committee, under the Chairmanship of R. G. Fuller, has plans well established for an outstanding 1954 Annual Summer Meeting. The distinguished Chairmen for the subjects to be presented include:

Homer Wood, Consulting Mechanical Engineer, AiResearch Manufacturing Company—Chairman, Accessory Design Problems Session.

John R. Moore, Associate Director of Electro-Mechanical Engineering Department, North American Aircraft, Inc.—Chairman, Electronics and Aircraft Electrical System Session.

Edgar Schmued, Vice-President in Charge of Engineering, Northrop Aircraft, Inc.—Chairman, Military Aircraft and Weapons Operation Session.

George Mellinger, Chief of Flight Test, North American Aircraft, Inc.—Chairman, Mechanical Problems of Flight Session.

John R. Poppin, Consultant in Aviation Medicine—Chairman, Human Problems of Flight Session.

Leo Carter, Vice-President and General Manager of Douglas Aircraft Co., Santa Monica Division—Chairman, Design Implications of Production Engineering and Tooling Session.

Dr. C. B. Millikan, Director of Guggenheim Aeronautical Laboratory, Southern California Cooperative Wind Tunnel—Chairman, Aerodynamics Session.

Jerome F. McBrearty, Chief Structures Engineer, Lockheed Aircraft Corporation—Chairman, Structures Session.

F. A. Cleveland, Bomber Group Engineer, Preliminary Design Division, Lockheed Aircraft Corporation—Chairman, CONFIDENTIAL Session on Aircraft Development.

These men are working with members of the Committee to select papers that will present fundamental educational and background material of real use to the aeronautical engineer in his daily work.

San Diego Section

H. C. Matteson
Corresponding Secretary

The San Diego Section concluded a year of highly successful activities with two meetings in December. At a technical meeting held on December 3, Arnold Ritter, of Convair, San Diego, presented a paper entitled "Application of the Interferometer to Aerodynamics." R. B. Johnston, of The RAND Corporation, presented his paper entitled "The Engineering Development of The Wright Brothers Airplane" at a dinner meeting held on December 10.

Mr. Ritter's broad experience in Germany with interferometers, both before and during the war, made him especially well qualified to discuss this interesting equipment and its application to wind-tunnel studies of airflow phenomenon. His paper included an excellent description of the interferometer and its operation. Motion pictures and slides were employed to show how the characteristics of the airflow about an oscillating airfoil may be quantitatively determined, as well as visually observed, by use of this equipment. A lengthy question-and-answer period followed Mr. Ritter's prepared talk.

Mr. Johnston gave a fine historical account of the engineering development of the first successful powered airplane. He emphasized that the engineering methods employed by the Wright brothers closely parallel present-day practice. Slides were utilized to illustrate the more interesting aspects of the design. Mr. Johnston noted that some of the design features employed on present-day aircraft were first conceived by the Wright brothers, including the first aileron-rudder interconnect system which was utilized to solve a lateral-directional stability problem. This talk was considered particularly appropriate for presentation during the Fiftieth Anniversary of Powered Flight and was thoroughly enjoyed by all in attendance.

A review of the proceedings of the San Diego Section over the past year shows a high degree of activity. Twelve technical meetings and eight dinner meetings were presented. In addition, a field trip and two dances were held. The enthusiastic response of the membership to this program has been most gratifying to the Section officers.

This was the first year in which the San Diego Section presented a comprehensive program of technical meetings. These meetings are held at a comparatively high technical level, and individually they are planned to appeal to specific technical groups. They have been especially well received by the members.

Plans are now being made to continue this successful program on an augmented scale during the coming year.

Seattle Section

Russell B. Light, *Secretary*

Randolph Hawthorne, Managing Editor of *Aviation Age*, was the speaker at the November 18 meeting of the Seattle Section. The subject of his talk was "Russian Airpower."

Mr. Hawthorne traced the development of several aircraft and engine types, and, with the aid of slides, showed the German influence on Russian designs. From his investigations of the growth of Russian airpower, Mr. Hawthorne is particularly impressed with the tremendous advances Russia has made since the end of World War II. Of special interest was his comment that the Russians were going underground with a large percentage of their aircraft industry.

Mr. Hawthorne's talk stimulated a great deal of interest, and an hour was spent answering questions from the audience.

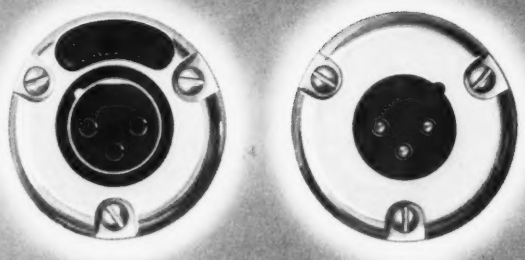
Student Branches

Alabama Polytechnic Institute

Thomas G. Groover, *Secretary*

On November 26, the Student Branch at Auburn was honored by a visit and a talk by George Baughman, Engineering Staff Specialist at Lockheed Aircraft Corporation's Georgia Division. After being introduced by Branch Chairman William Morgan, Mr. Baughman gave a most informative talk on the design and evolution of single-strut landing gear. Fifty student members were present.

Plans are being made to entertain the Annual Southeastern Conference of the IAS Student Branches at Auburn in the spring. Everyone is looking forward to meeting students from other branches and to comparing notes with them.



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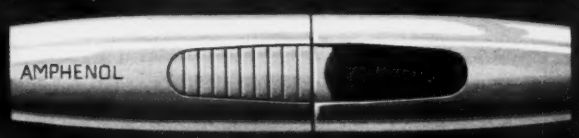

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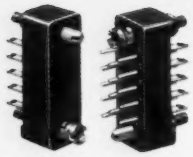

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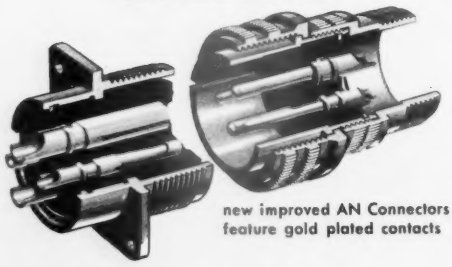

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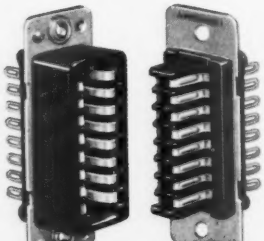

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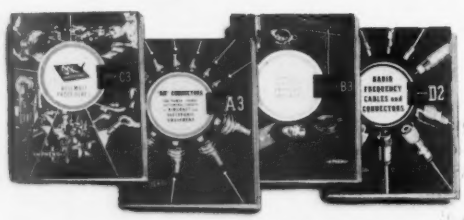

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Cal-Aero Technical Institute

James K. Carmody
Secretary-Treasurer

The Cal-Aero Student Branch held a dinner meeting in October at the American Legion Banquet Room in Glendale.

The activities started with a social hour from 7:00 to 8:00 p.m. After dinner, which was served at 8:00 p.m. sharp, came our pièce-de-résistance, an address by Major Charles E. (Chuck) Yeager, USAF. Major Yeager had just returned from Japan where he had made flight tests on the MIG-15. The Major was unable to tell about his experiences with the MIG-15, but he did give us all the details leading to his first flight through the "sonic barrier."

We had a "mixed crowd" dinner, and Major Yeager, therefore, brought his lovely wife. Mrs. Yeager is quite an ardent fan of her famous husband and told us that she seldom has the opportunity to listen to him speak in as much as most dinners of this type are too technical for ladies.

▶ The month of November was climaxed by a visit to the Cal-Aero Student Branch by Cliff Land, Assistant Personnel Manager of AiResearch Manufacturing Corporation. Mr. Lang gave a remarkable address on the proper approach in applying for a professional job. His speech was so thorough in all aspects that hardly a question was asked at the conclusion of his talk.

Major Charles E. (Chuck) Yeager, USAF *(center)* was the speaker at the October dinner meeting of the Cal-Aero Technical Institute Student Branch. Shown with Major Yeager are James K. Carmody, Secretary-Treasurer *(left)*, and James N. Bishop, Chairman.

Catholic University of America

Robert E. Kastner, *Secretary*

On December 9, the IAS Student Branch at Catholic University of America held its first meeting of the present academic year. After calling the meeting to order, Chairman William Elsen welcomed the old members as well as the new faces present. He then outlined the program for the remainder of the year, stating that, because of the great number of speakers obtained by our Faculty Advisor, William Miller, there was a possibility of having more than one meeting a month.

The speaker of the meeting was Abraham Hyatt from the Research Division of the Navy's Bureau of Aeronautics. He spoke on "Interesting Phases of Airplane Design." He first outlined the functions of BuAer and then went on to discuss the various things that must be taken into consideration when designing an airplane. Mr. Hyatt emphasized the complexity of modern aircraft and the effect that the components of an airplane have on its ultimate design.

Parks College of Aeronautical Technology

Myron Tygar, *Secretary*

Treasurer Beasley reported at the December 3 meeting that, as of this date, the Student Branch has 52 members, seven of whom joined since the last meeting. Forty persons attended the December 3 meeting.

Chairman Frederic Weisman reminded the members that the Second Annual Student Paper Competition, sponsored by the IAS Texas Section, will be held on April 21–24, 1954. He expressed the hope that this branch would repeat its success of last year.

The speaker was Dr. Robertson, Professor, St. Louis University's Institute of Technology. In her paper on "Electrical Properties of the Upper Atmosphere," Dr. Robertson explained many of the common electrical phenomena that cause disturbances in electrical and electronic equipment. At the conclusion of her talk, an informal question-and-answer period was held.

United States Naval Academy

Midshipman Robert M. Hemings, Jr.
Secretary

One hundred students gathered on November 30 to hear Robert G. Barnhart, Military Liaison Department, Piasecki Helicopter Corporation, speak on the "Commercial and Military Use of the Helicopter." Chairman Don Walsh, Midshipman 1/c, presided.

Mr. Barnhart gave an interesting speech on the various tests that are run and the requirements that must be met before an aircraft could be accepted by the military. The speaker gave a description of the "destruction tests" conducted by his company in determining the characteristics of various types of helicopters. Two films were shown in conjunction with the talk, one on the history of the helicopter and the other on its military uses.

University of Illinois

David G. Herbener, *Secretary*

On December 9, a meeting was held jointly with the recently formed Rocket Society. Vice-Chairman Dwight A. Moberg presided; 47 students were present.

After a brief business session, Dr. K. Z. V. Krzywoblocki, the speaker of the evening, was introduced. Dr. Krzywoblocki, professor of Aeronautical Engineering at Illinois, spoke on the topic "The Elements of the Theory of Flight of a Missile." In his talk, he touched upon the history of the development of

missile flight, the correlation of ballistics and aerodynamics, and some of the problems encountered in high-speed flight.

University of Tulsa

William A. Keeler
Secretary-Treasurer

The meeting of December 17 was called to order at 7:30 p.m. by Chairman Jack Owens. The total attendance was 20.

After the business portion of the meeting was concluded, a fine talk on the Fiftieth Anniversary of Powered Flight was delivered by Bob Wolfe. Mr. Wolfe spoke on the Wright Brothers first flight and the advances made in aviation since December 17, 1903.

Three films were shown following Mr. Wolfe's talk. These were two U.S. Navy films, *The Training of a Naval Cadet* and *The Cavalcade of Aviation*, and one from General Electric Company, *The Jet Story*.

The meeting was adjourned at 9:45 p.m.

West Virginia University

Benjamin D. Grove
Corresponding Secretary

The November 18 meeting was begun with a short business session, after which all attending visitors and members were introduced. The program consisted of a presentation of information on summer employment by those student members who had had such experiences this past summer. Emmette Wilson spoke on conditions at Aeronca Manufacturing Corporation, and Malcom Ullock told of working for United Aircraft Corporation's Chance Vought Aircraft Division.

▶ The meeting of December 9 was called to order by Chairman Malcom Ullock. During a discussion of ways in which to increase membership, Prof. L. Z. Seltzer proposed that a letter be prepared and distributed at registration to all students taking aeronautical courses.

The program for the evening was presented by Charles Bartlett who gave a review of his employment during the last two summers at The Glenn L. Martin Company. Two films, *History of the Helicopter* and *Thunderstorms*, concluded the evening's program.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Hagger, George F., B. of Ae.E., Dir. of Engrg., Aero Supply Mfg. Co., Inc.

Transferred to Associate Fellow Grade

Bouton, Innes, B.S.E. (Aero.), Member, Subcommittee on Aircraft Loads, NACA (Washington, D.C.); Airplane Chief Loads Engr., McDonnell Aircraft Corp.

Brahtz, John F. P., Ph.D., Assoc. Prof.-Engrg., Univ. of California.

Chapman, Dean R., Ph.D., Aero. Research Scientist, NACA (Moffett Field).

Goldman, George M., B.Sc. in Ae.E., Chief, Design Criteria Section, Struct. Br., WADC.

Monroe, Gerald M., Ph.D. Aero., Lt. Comdr., USN; Design Proj. Engr., Devel. Group, Chance Vought Aircraft, Inc. (Dallas).

Elected to MEMBER Grade

Arenson, Donald L., M.S., Tech. Dir., Aerophysics Section, Cook Research Labs. Div., Cook Electric Co.

Brunner, Mathias J., M.S.M.E., Design Engr., Westinghouse Electric Corp.

Carmody, Edmund O., A.B., Contracts & Sales Mgr., Stanley Aviation Corp.

Coleal, William A., B.S.A.E., Research Engr., Lockheed Aircraft Corp. (Burbank).

Dennis, Ward B., M.S., Asst. Chief, Weapon Systems Analysis Dept., Northrop Aircraft, Inc.

Foster, William W., Jr., M.Sc., Lt. Col., USAF, assigned to Convair (Ft. Worth).

Garrard, Wilfred C. J., Ph.D. (Aero.), Aerodynamics Engr., Chance Vought Aircraft, Inc. (Dallas).

Grina, Kenneth I., B.Aero.E., Asst. Chief of Struct., Piasecki Helicopter Corp.

Gwathmey, Edward S., Ph.D. in Physics, Member, Bd. of Directors, Feed Products, Inc.; Dir. of Research, Specialties, Inc.

Holdhusen, James S., Ph.D., Secy. & Chief Research Engr., FluiDyne Engrg. Corp.

Holmquist, Carl O., Ph.D. in Aero., Lt. Comdr. & Proj. Engr. & Proj. Pilot, USN, NATC (Patuxent River).

Jeffrey, Joseph D., B.S.Ae.E., Lt. Comdr. & Student, Naval War College, USN (Newport, R.I.).

Jones, Ben F., B.S.M.E., Tech. Supt., B. F. Goodrich Co.

Keltto, Homer S., B.S. in Ae.E., Engrg. Designer, Marquardt Aircraft Co.

Kirchner, Otto E., Jr., M.B.A., Systems Analysis, Boeing Airplane Co. (Seattle).

Kliever, Waldo H., Ph.D., V.-P., Dir., Instrument Devel., Clevite-Brush Devel. Co.

Lankford, John L., B.S. in M.E., Research Engr., Central Research Lab., Melpar, Inc.

Loewen, Walter R., B.S., Staff Engr., Temco Aircraft Corp.

Marlow, Wayland C., M.S., Prelim. Design Engr., Fairchild Aircraft Div., Fairchild Engine & Airplane Corp. (Hagerstown).

Matthews, Arthur F., Asst. Proj. Engr., McDonnell Aircraft Corp.

Newman, Joseph W., A.A., Air Force Quality Control Rep., Western Air Procurement District, USAF assigned to Marquardt Aircraft Co.

Palsulich, Joseph, M.E., Asst. Chief Engr., Aircraft & Allied Products, Cleveland Graphite Bronze Co.

Petersen, Forrest S., M.S.E., Lt. & Maint. Officer, High Performance Jet Fighter Sq., U.S. Naval Pacific Fleet, USN.

Peterson, Harold W., Jr., Engrg. Test Pilot, Piasecki Helicopter Corp.

Prust, Michael C. B., Engr. "B," Functional Procedure Group, Canadair, Ltd.

Rapp, George C., B.S.M.E., Propulsion System Planning Engr., General Electric Co.

Saylor, James M., B.S.A.E., Aerodynamics Engr., Lockheed Aircraft Corp. (Marietta).

Shakespeare, William B. J., Engr. "A," Canadair, Ltd.

Smith, Charles B., M.S., Lt. & Naval Aviator, USN.

Sutton, Matthew A., M.Sc. in Ae.E., Instructor & Research Assoc., Dept. of Aero. Engrg., The Ohio State Univ.

Van Norman, Allen, B.A., Design Engr., Convair (San Diego).

Vierling, Bernard J., B.S.M.E., President, Aircraft Supply Corp.

Westbrook, Henry W., B.A.E., Designer "B," Boeing Airplane Co. (Seattle).

Wittrick, William H., Ph.D., Sr. Lecturer in Aeronautics, Univ. of Sydney (Australia).

Zloe, Edward D., M.B.A., Engr. in Charge, Dept. 5851, Eclipse-Pioneer Div., Bendix Aviation Corp.

Transferred to MEMBER Grade

Busch, Gerald A., Masters Degree in Economics, Devel. Engr., Devel. Planning Dept., Lockheed Aircraft Corp.

Caldwell, Allan L., M.Sc. in Ae.E., Aerodynamicist, Douglas Aircraft Co., Inc. (El Segundo).

Connor, Thomas C., B.S. in M.E. & B.S. in Ae.E., Proj. Engr., Aircraft Engine Div., Packard Motor Car Co.

Conrad, Harold L., B.S.Ae.E., Inspection Flight Test Engr., North American Aviation, Inc.

Dalley, Joseph W., M.S. Engrg. Mechanics, Asst. Prof. & Research Engr., Univ. of Texas.

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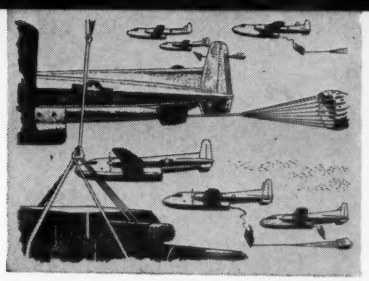

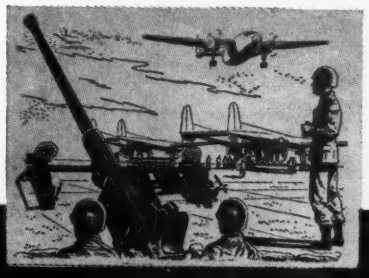

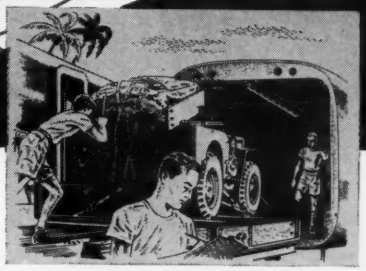

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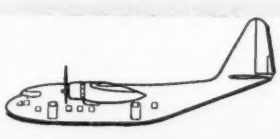

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Houston, Robert R., Staff Engr., Special Projects, Pan American World Airways.

Joslyn, Warren A., A.E., Stress Analyst "A," Boeing Airplane Co. (Seattle).

Kavanau, Lawrence L., M.S.E.Ae.E., Research Engr., Univ. of California (Berkeley).

Elected to Associate Member Grade

Boom, William E., B.A., European Rep., Simmonds Aerocessories, Inc.

Floberg, John F., LL.B., Partner-Law Firm of Kirkland, Fleming, Green, Martin & Ellis.

Marsh, William A. G., Mech. Engr., Canadair, Ltd.

Walker, Thomas W., Mgr., Aircraft Controls Dept., The Thermix Corp.

Elected to Technical Member Grade

Anastasio, Robert F., B.S., Aero. Research Scientist, NACA, Ames Aero. Lab.

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Gerig, Roland, B.A.Sc.Ae.E., Asst. Engr., Field Aviation Co., Ltd.

Gotthardt, Charles J., Jr. Electronic Engr., Devel. Labs., Pacific Div., Bendix Aviation Corp.

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Schulthess, Heiner P., Dipl. Eth., Perform. & Operation Engr., Swissair.

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Thiessen, Dewey A., B.S. in M.E. (Aero.), Struct. Engr., Chance Vought Aircraft, Inc. (Dallas).

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Hanzlik, Jack E., B.S.Aero., 2nd Lt. & Student Pilot, USAF (Stallings Air Base).

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Krell, Jordon A.

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Murphy, Roy S., Jr. Design Engr., North American Aviation, Inc. (Downey),

Otis, David R., M.S. in M.E., Thermodynamics Engr., Convair (San Diego).

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Powell, K. Harmon.

Rathbun, Kenneth C., M.E., Research Assoc., Propulsion Dept., Experiment, Inc.

Reynolds, Betty J., B.S. in Ae.E., Jr. Engr., Aerodynamics Div., Chance Vought Aircraft, Inc.

Richardson, Edwin L., B.S. in Ae.E., Flight Test Pilot, General Electric Co. (Schenectady).

Schmitt, Robert J., B.S. in Ae.E.

Scott, Bernard C., B.S., Exp. Test Engr., Allison Div., General Motors Corp.

Sebold, Robert A., B.S. in Ae.E., Jr. Engr., Republic Aviation Corp.

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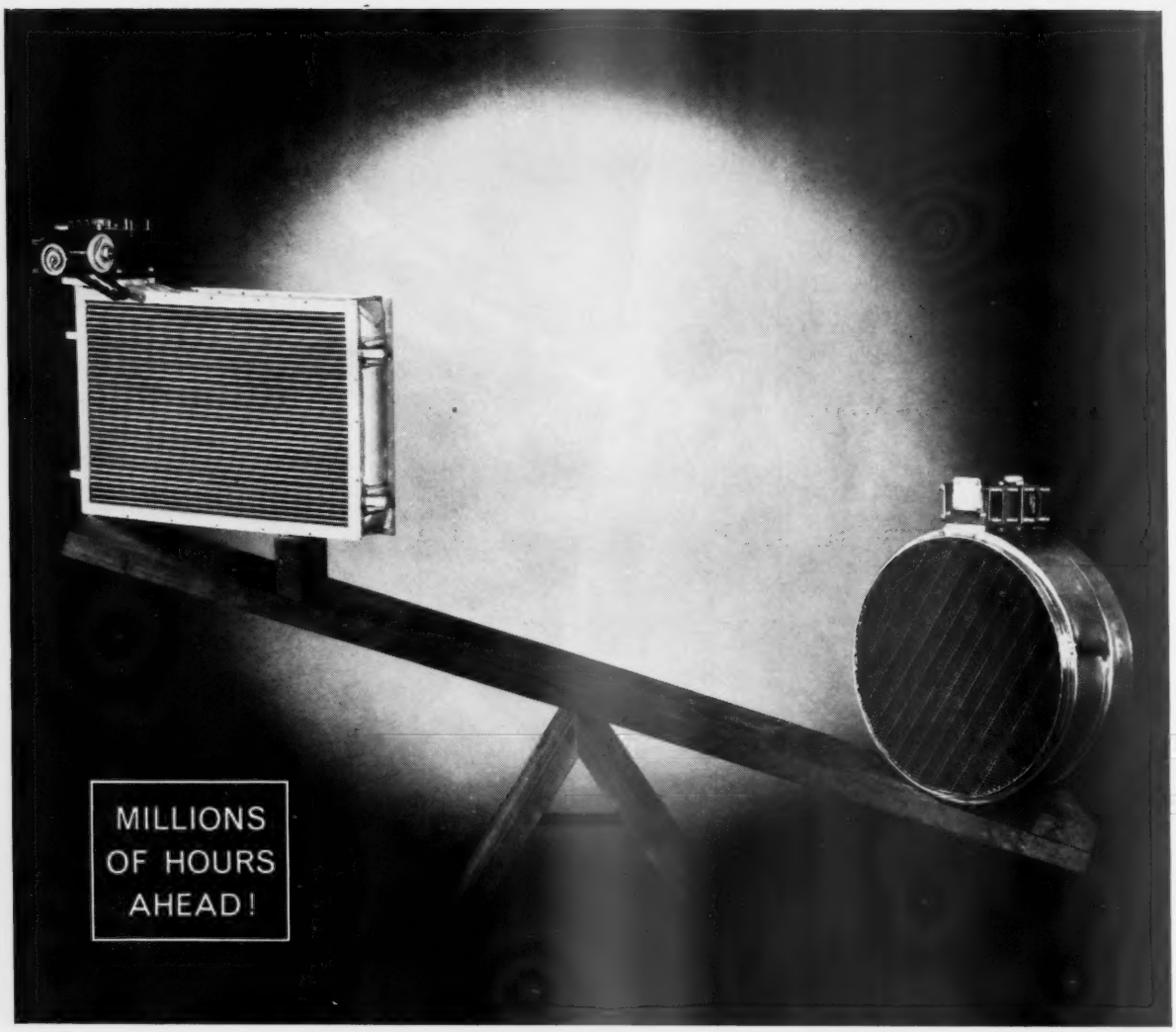

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Determination of the Flying Qualities of the Douglas DC-3 Airplane. Arthur Assadourian and John A. Harper. *U.S., NACA TN 3088*, Dec., 1953. 67 pp.

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Effect of Type of Porous Surface and Suction Velocity Distribution on the Characteristics of a 10.5-Percent-Thick Airfoil with Area Suction. Robert E. Dannenberg and James A. Weiberg. *U.S., NACA TN 3093*, Dec., 1953. 59 pp.

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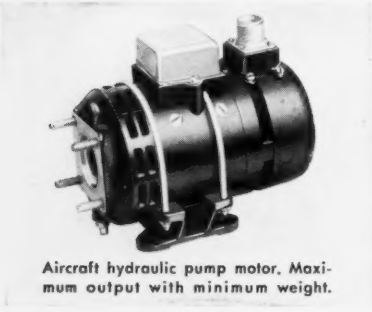

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DOW CORNING

Silicone News

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New Data Reveals Effect of Heat Aging on Properties of High Temperature Laminates

Comparative studies of the effect of heat aging on light weight structural materials indicate that the better resin bonded glass laminates compare very favorably with light metals at high temperatures. These studies made recently by our engineers and summarized below in Table I show that the laminates have greater tensile strength than the metals at 500 F after aging for as little as half an hour at that temperature.

Tensile strength to weight ratio for the laminates is also superior to that of the metals under the same conditions. Measured at 500 F after 200 hours at that temperature, the tensile strength to weight ratio times 10^{-2} for the silicone-glass laminates is in the range of 4 to 5 times comparable values for the light metals.

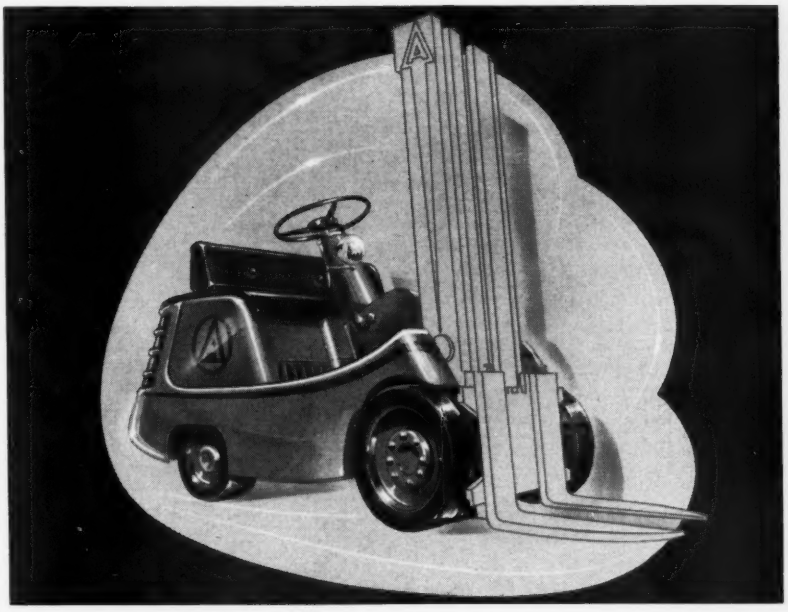
The organic resin bonded glass laminates show excellent short term retention of mechanical strength at 500 F. Strength falls off quite rapidly, however, with increasing time. The mechanical properties of the silicone-glass laminates at 500 F decrease during the first half hour and then improve or remain unchanged with increasing time. Weight loss, water absorption and dielectric properties of the silicone-glass laminates are markedly superior.

Included in this study were glass laminates bonded with several new, heat resistant low pressure phenolic, polyester and

(*continued pg. 2*)

TABLE I
EFFECT OF HEAT AGING ON HIGH TEMPERATURE LAMINATES AND LIGHT METALS

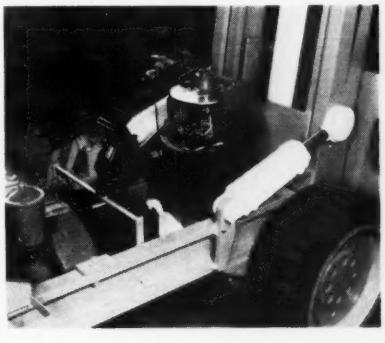
Property	High Pressure Silicone	Low Pressure Silicone	Low Pressure Polyester	Low Pressure Phenolic	Aluminum	Magnesium
Flexural Strength, psi						
As received	45-47,000	27-32,000	45-55,000	44-66,000		
At 500 F after						
½ hr at 500 F	5,000	12-15,000	35,000	41-50,000		
200 hr at 500 F	19,000	12-15,000	11-25,000	9,000		
Tensile Strength, psi						
As received	26-32,000	35,000	33-36,000	22-27,000	50-65,000	39-42,000
At 500 F after						
½ hr at 500 F	8-10,000	22-25,000	30-33,000	24-29,000	7-13,000	8,000
200 hr at 500 F	18-20,000	20-22,000	9,200	11-15,000	5-9,500	6,000
Density, g/cc	1.65-1.80	1.70-1.85	1.65-1.85	1.50-1.80	2.7	1.76-1.80
Tensile Strength to Weight ratio x 10^{-2}						
½ hr at 500 F	5.3	13.6	18.0	16.1	1.7	3.5
200 hr at 500 F	11.0	12.2	5.3	7.9	2.7	3.3
Weight Loss, percent						
200 hr at 500 F	0.35-1.31	0.1-0.2	9.00	11.2		
Water Absorption, percent (After aging 200 hr at 500 F)	0.21	1.0-1.3	2.00	9.00		
Dielectric Strength, v/m, ⅛" electrodes						
As molded	80-100	300	90	200		
Aged 200 hr at 500 F	80-100	80-100	70	60		
Power Factor, percent						
As received, at 10^5 cps	0.14	0.22	1.2	2.7		
Dielectric Constant						
As received, at 10^5 cps	3.90	4.13	4.00	4.31		
Arc Resistance, sec.						
As received	300	350	185	165		



Designers Use Class H Insulation to Sell More Electric Machines in Buyer's Market

Instead of viewing with alarm our entry into a more normal competitive economy, Automatic Transportation Company has prepared for it. They have developed a new product with many strong selling features, including more continuous operation with minimum maintenance cost.

"Dynamotive", Automatic's newest entry in the materials handling equipment market, has so many new features that it bears little resemblance to the lift truck of 5 or 10 years ago. The first gas-powered, electrically driven fork lift truck, it has an electrical system that assures long service life by making it impossible to reverse the direction of the truck while it is in motion.



Engine wear and fuel consumption are minimized by an electrical transmission with its inherent overdrive feature that

(*continued pg. 2*)

DOW CORNING Silicone News

NEW DEVELOPMENT AND TECHNICAL DATA

For copies of any of the publications reviewed in this column or for data relating to any of the articles printed in this issue of the Dow Corning Silicone News, simply circle the corresponding reference number on the coupon below.

Silicones have captured the interest of imaginative designers. And it's not all idle thinking because the properties of these unique materials enable engineers to effect their ideas in new products and applications. A reprint of a recent BUSINESS WEEK article reviews some of the existing uses for silicones and forecasts many new silicone products for the industrial and consumer markets. *No. 44*

●

The use of bare magnet wire insulated with Dow Corning Wire Enamel makes possible longer life, increased reliability and reduction in size and weight of electronic devices, fractional and miniature motors. Accelerated tests at temperatures in the range of 200 to 275 C indicate its long term serviceability at temperatures up to 190 C (374 F.) A list of electrical wire manufacturers, who make such wire available in various sizes, is yours for the asking. *No. 45*

●

New source of supply list names more than 60 formulators supplying durable protective coatings made with silicone vehicles. Available coatings include white and colored silicone appliance enamels that withstand temperatures up to 700 F; aluminum pigmented finishes which minimize maintenance of exhaust stacks exposed to corrosive atmospheres and temperatures up to 1000 F; and modified silicone-organic paints that offer increased stability, greater resistance to temperature extremes, weathering, oils and greases. *No. 46*

●

The 1954 Reference Guide to Dow Corning Silicone Products summarizes properties and briefly describes applications for commercially available silicones including several new products. Containing a wealth of useful information about silicone products, the Guide belongs in every designing and engineering reference file. *No. 47*

●

Reprint of a recent article "Silicones In Packaging" describes how various silicones are used to advantage in handling, processing and packaging drugs and pharmaceuticals, baked goods, foods and beverages. *No. 48*

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New Silicone Coating Prevents Adhesion and Build-up on Rolls, Slashers and Drying Cans

A recently developed silicone product called Dow Corning XF-121, is proving to be a highly effective and economical coating for rolls, slashers, and drying cans used in the textile industry.

Properly applied, Dow Corning XF-121 forms a tough, resilient film which reduces the adhesion and minimizes build-up of such warp or sizing materials as starch, gelatin, synthetic rubber latices and styrenated resins. On high production units, only thin coatings are required to reduce scrap due to build-up, and to substantially reduce down time and maintenance costs.

Dow Corning XF-121 can be applied without dismantling equipment. Cost is only about 1% of the cost of the only other coating now available that gives comparable performance. In most applications, less than 4 pounds of Dow Corning XF-121 will cover 100 square feet of roll area. Reports indicate that even such thin coatings provide several weeks or months of service, depending on operating conditions. Production increases up to 50% have also been reported.

Supplied as a solvent solution with a 25% silicone content, Dow Corning XF-121 can be applied as received, or it can be thinned with additional solvent and applied by brush or spray. Properly catalyzed, it will air dry and cure overnight or it may be cured by heating for 1/2 to 1 hour at 200 F. The film is easily removed with a wide spatula or putty knife.

No. 41

DESIGNERS USE CLASS H *(continued)*

automatically adjusts engine speed to load requirements. The engine and motor always run at the most efficient speed.

And to obtain still longer, more dependable service life, the generator and motor of the "Dynamotive", like all Automatic motors built since 1946, are protected with Class H insulation made with Dow Corning silicones. Automatic Transportation engineers report that: *"silicone insulation is used because it contributes to longer life and can take more abuse than other insulating materials. Since we adopted it over 7 years ago we have never, to our knowledge, lost a motor due to insulation failure."*

That's the kind of performance that has sold more and more electrical equipment manufacturers and their customers on the value of silicone (Class H) insulation. They know from experience that Class H can be used to increase the power per pound ratio in electric machines by at least 50% without loss of efficiency. And, even more important in a buyer's market, they know that Class H outlasts ordinary insulation 10 to 1. *No. 42*

EFFECT OF HEAT AGING *(continued)*

silicone resins. The high pressure, silicone-glass laminate specified under NEMA Grade G-7 (LPI-1951) and MIL-P-997B was selected as a standard of comparison.

Style 181 glass cloth, heat treated for the silicone resins and Garan finished for the organics, was used for all laminates. Test samples were cut from 1/8" sheets which had been cured according to the resin manufacturers' recommendations.

High pressure silicone-glass laminates were press cured at 350 F followed by a graduated cure in an oven at temperatures ranging from 194 to 392 F for a total of 24 hours. The low pressure silicone-glass laminates were aftercured for 150 hours at 482 F.

The tests included in this study were conducted according to Fed. Spec. L-P-406b. Flexural and tensile strengths were measured at test temperatures. Water absorption, dielectric strength and weight loss were measured at room temperature after aging for 200 hours at 500 F. Arc resistance, power factor and dielectric constant were measured at room temperature after curing.

No. 43

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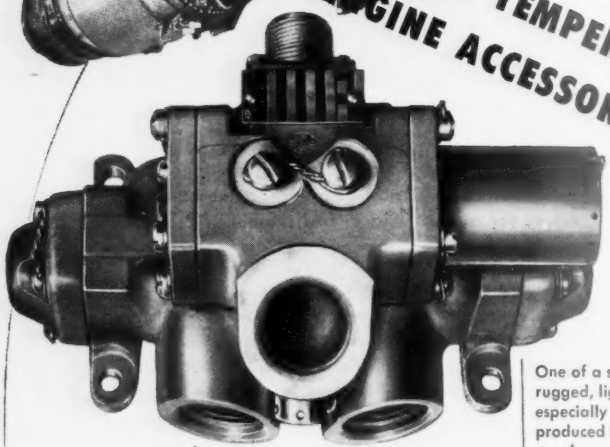

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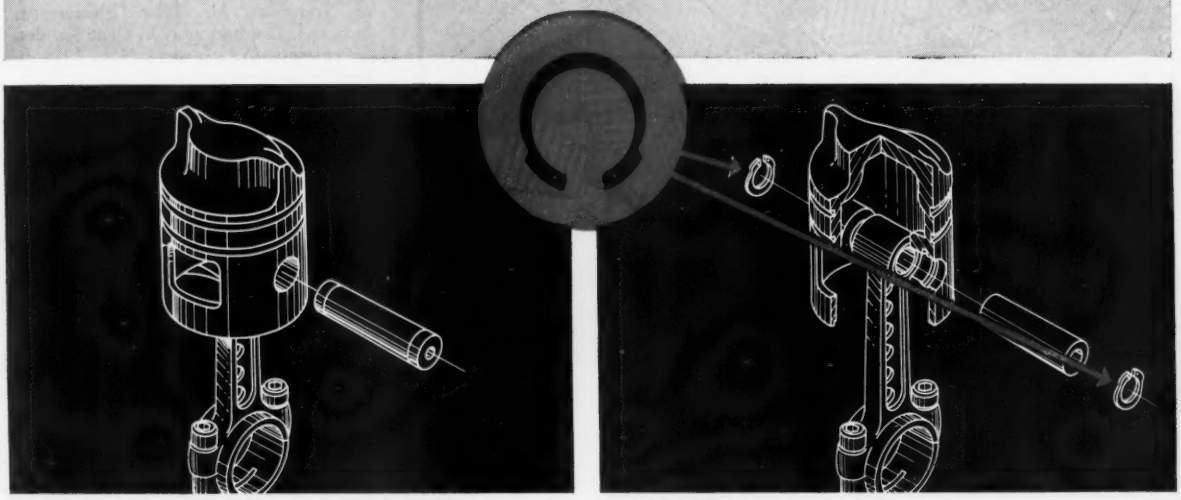

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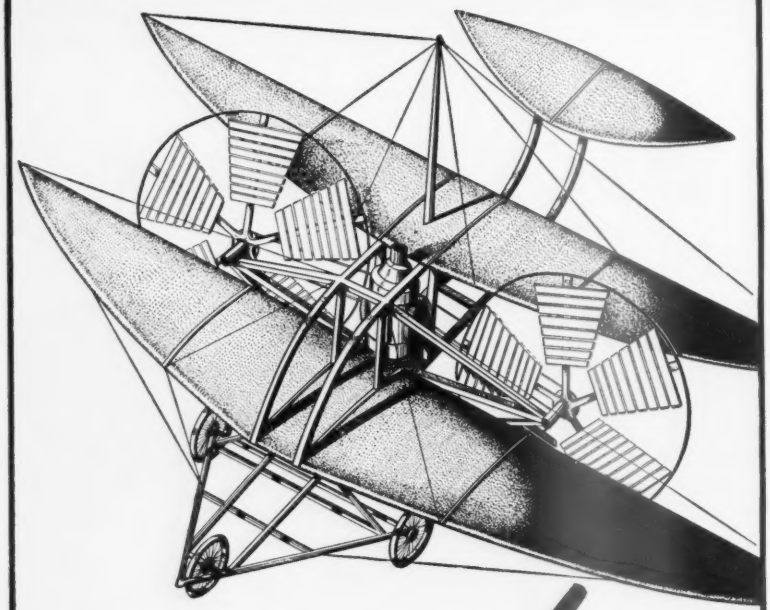

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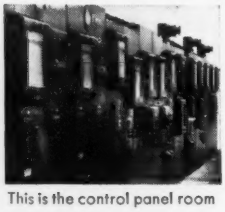

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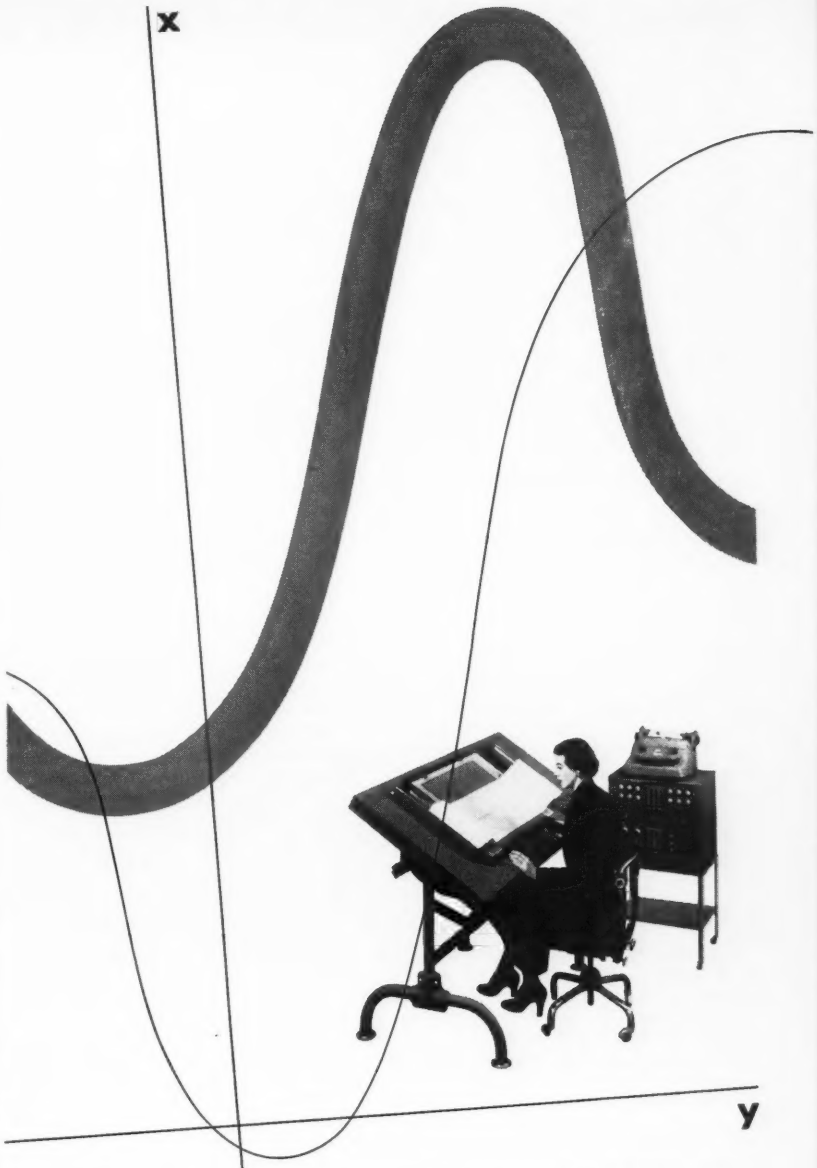

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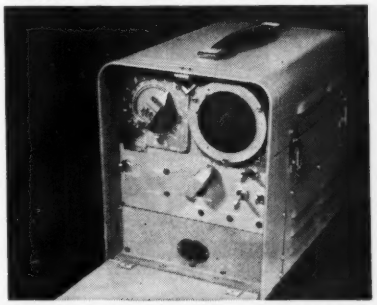

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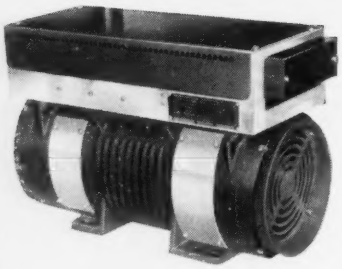

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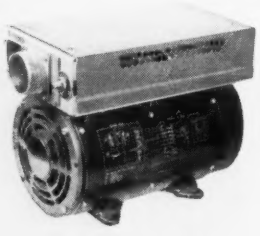

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Specifications
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(Conforms to USAF drawing 53B6227 and AN-I-10b)

Input DC	
Voltage Range	26 to 29
Current Range	160 to 180
Current at 27.5 volts	165
Output AC	**Single Phase**
Volts	115±4%
Amperes	21.7
Volt-Amperes	2500
Frequency-cps	400±10
Power Factor	.9 lag to .95 lead
Efficiency	55%
200% load	5 sec.
150% load	5 min.

WEIGHT: Approximately 62 pounds.

MAXIMUM OVER-ALL DIMENSIONS: 7¼" wide x 11¼" high x 17" long.

ALTITUDE	AMBIENT TEMP. RANGE
Sea Level	−55°C to +85°C
35,000 ft.	−55°C to +40°C
50,000 ft.	−55°C to +20°C

Type MG-54
(Conforms to Navy drawing E-51A1A9 and MIL-I-7032)

Input DC	
Voltage Range	26 to 29
Current Range	24.1 to 21.6
Current at 27.5 volts	22.8
Output AC	**Three Phase**
Volts	115/200±4% (115±4%, single phase)
Amperes	1.25/.723 (2.17, single phase)
Volt-Amperes	250 (single phase, three phase, or single and three phase combined)
Frequency-cycles/sec.	400±10
Power Factor	0.8 lag to .95 lead
Watts at 0.8 PF lag	200
Efficiency	40%
200% load	5 sec.
150% load	5 min.

WEIGHT: Approximately 17 pounds.

MAXIMUM OVER-ALL DIMENSIONS: 5½" wide x 8" high x 12" long.

ALTITUDE	AMBIENT TEMP. RANGE
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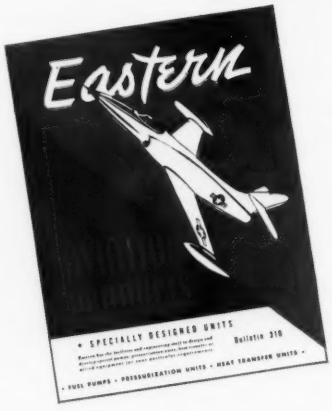

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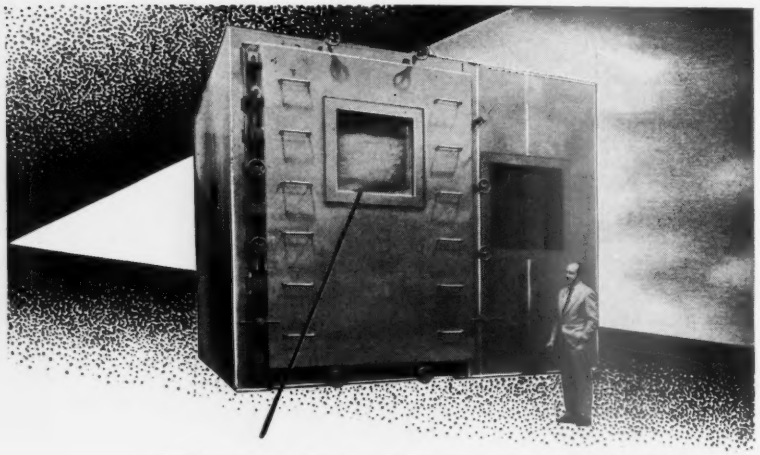

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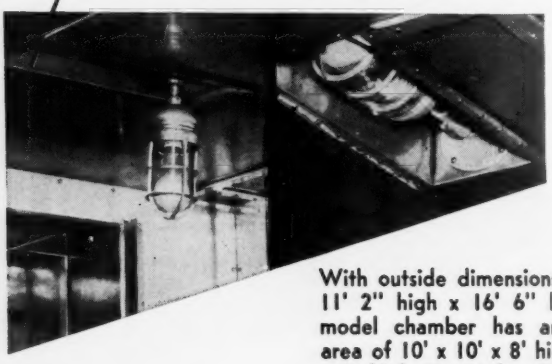

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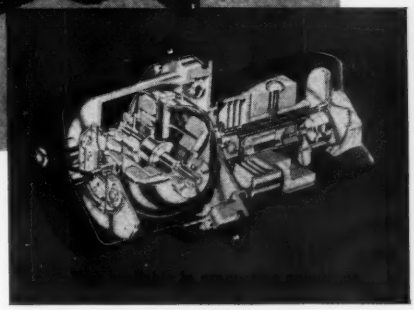

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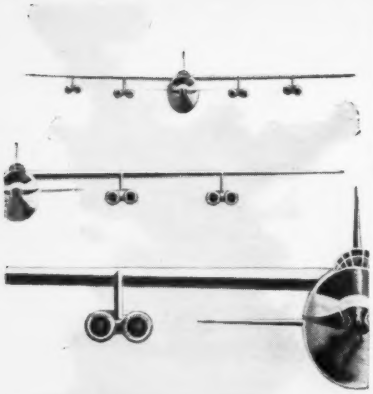

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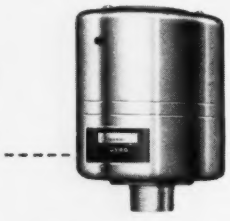

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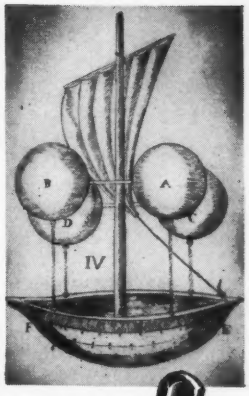

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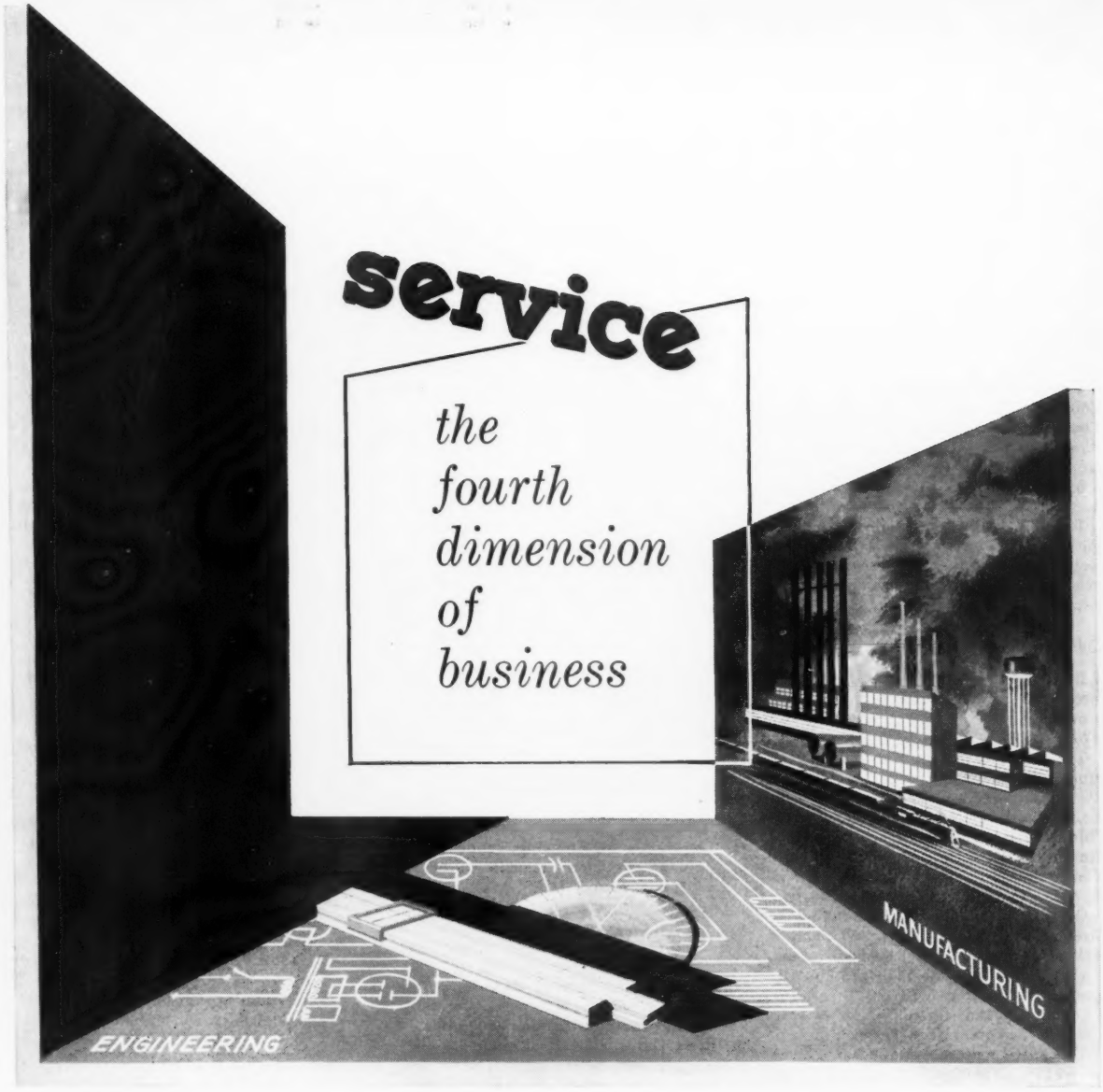

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$$T_{\xi\xi} + T_{\eta\eta} = \eta T_{\xi}$$

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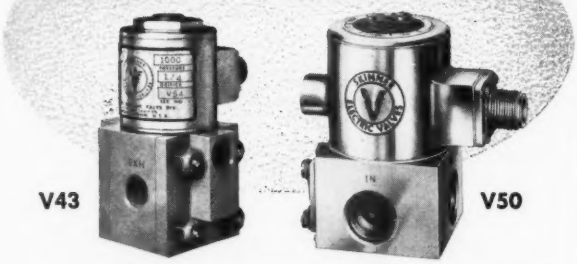

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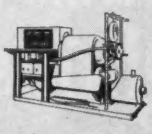

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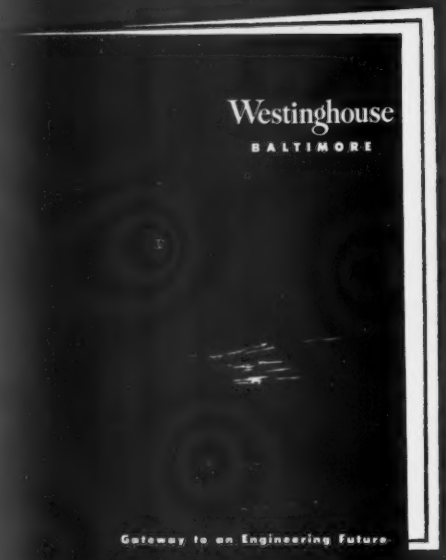

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Engineers—The U.S. Naval Air Rocket Test Station has several vacancies in the Engineering Department: **Electronic Engineer**—GS-9, $5,060 per annum. Duties: As an engineer in the development section of the instrumentation branch of the power-plant division, designs and develops new instrumentation systems and modifies existing systems used in testing rockets or associated components. **Electronic Engineer**—GS-5, $3,410 per annum. Duties: As an engineer in the development section of the instrumentation branch of the power-plant division, installs instrumentation and calibrates and operates instrumentation in existing rocket testing installations. Assists in the design and layout of new instrumentation systems. **Electronic Engineer**—GS-9, $5,060 per annum. Duties: Project engineer in the installation section of the instrumentation branch of the power-plant division. Designs new instrumentation systems and modifies existing systems used in testing rockets or associated components. Directs and supervises other members of the instrumentation branch in installing, calibrating, and operating instrumentation systems. **Electronic Engineer**—GS-7, $4,205 per annum. Duties: As an engineer in the installation section of the instrumentation branch of the power-plant division, cooperates in the design of new instrumentation and modification of existing testing facilities. Performs experiments on instruments and allied equipment to ascertain characteristics of same. **General Engineer (Editing)**—GS-9, $5,060 per annum. Duties: Head of the technical publications branch of the engineering services division of the engineering department. Responsible for editing, compiling, preparing for publication, and distributing of all technical reports issued by the engineering department. **General Engineer (Editing)**—GS-7 $4,205 per annum. Duties: Technical editor in the technical publications branch of the engineering services division of the engineering department. Responsible for assisting the Branch Head in editing, compiling, and preparing for publication all technical reports issued by the engineering department. **Engineering Draftsman**—GS-6, $3,795 per annum. Duties: As a design draftsman in the design branch of the power-plant division, originates designs and layouts relating to the mechanical design of experimental rocket engines, rocket engine accessories, and rocket engine test facilities. **Chemical Engineer**—GS-11, $5,940 per annum. Duties: Project engineer and assistant to head of special projects branch of the propellant division. The special projects branch is concerned with the theoretical performance of liquid and solid propellant systems, advanced thermodynamics, chemical kinetics of combustion and explosion processes, and other problems concerning propellants when used for rocket propulsion. **Mechanical Engineer**—GS-9, $5,060 per annum. Duties: As an engineer in the propellants division, conducts projects relative to the test and evaluation of liquid propellants for rocket engines. Applicants should complete Standard Form 57, application for Federal Employment, which is available at any Post Office, and forward to the Industrial Relations Officer, Industrial Relations Department, U.S. Naval Air Rocket Test Station, Lake Denmark, Dover, N. J.

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Professor or Instructor—To teach undergraduate and graduate courses in structural and stress analysis and aeroelasticity or design. Advanced degree and some industrial experience desirable. Opportunity for research. Salary and rank dependent upon qualifications. Address inquiries, including résumé of education and experience and photograph, to Director, Guggenheim School of Aeronautics, Georgia Institute of Technology, Atlanta, Ga.

Fluid Dynamicists—The Applied Physics Laboratory of The Johns Hopkins University, located in Silver Spring, Md. (suburban Washington), has several research positions open for theoretical and experimental fluid dynamicists. Qualified applicants may find an opportunity for basic research in hypersonic flow, shock-wave phenomena, turbulence, and some other fields of fluid dynamics.

Research Aerodynamicists, Physicists, Chemists, Mathematicians, Metallurgists; Chemical, Electronic, and Structural Research Engineers—The Research Division of Ordnance Missile Laboratories seeks qualified applicants in the above categories. Employees will participate in a variety of stimulating research activities dealing with problems in aerodynamics, propulsion, guidance, materials, etc. Positions exist for grades GS-5 through GS-14 with corresponding salaries from $3,410 to $9,600 per annum. Ordnance Missile Laboratories is the Army Ordnance research and development center for rockets and guided missiles. It is located in the TVA lake region of North Alabama. Applications may be submitted on Form 57, Application for Federal Employment, which is available at any first- or second-class Post Office or from any Civil Service Regional Office. Correspondence should be addressed as follows: Commanding General, Redstone Arsenal, Huntsville, Ala., Att: H. W. Smith, Civilian Personnel Division.

Engineers—Opportunities for employment exist in the Bureau of Aeronautics, Department of the Navy, Washington, D.C. **Aerodynamics Development Engineer (Hydrodynamics)**—GS-9, $5,060 per annum; GS-11, $5,940 per annum; or GS-12, $7,040 per annum. Duty post: Washington, D.C. Work assignments include the initiation and monitoring of hydrodynamic research projects and contracts required for the development of Navy seaplanes; analyze technical reports, project results, and hydrodynamics data; prepare hydrodynamic design requirements; prepare demonstration requirements and special test requirements. Tow tank experience desired; familiarity with practices and procedures of hydrodynamics research and develop mandatory. **Aircraft Structural Loads Engineer**—GS-11, $5,940 per annum. Duty post: Washington, D.C. Review, analyze, and evaluate structural air loads reports for compliance with design specifications; establish structural flight demonstration requirements; investigate structural load problems in experimental aircraft and guided missiles; assist in the preparation of contract specifications. Experience and knowledge of methods of determining structural air loads are required. **Aircraft Structural Loads Engineer**—GS-12, $7,040 per annum. Duty post: Washington, D.C. Work assignments include planning, initiation, and follow-through on programs and projects relating to structural ground loads of Naval aircraft; critical analyses of contractor reports pertaining to ground loads and the approval or disapproval of such data in view of contract requirements; the investigation of special ground loads problems in connection with armament items and arresting and catapult requirements; structural engineering administration of field landing tests and carrier suitability tests. Requires experience and knowledge of all ground and handling loads and methods and procedure for analyses for such loads. **Mechanical Engineer**—GS-12, $7,040 per annum. Duty post: Washington, D.C. Duties include responsibility for conducting investigations, studies, and projects in gas dynamics; serves as expert, specialist, and consultant in gas dynamics for the purpose of guiding the development of advanced naval aircraft power plants. **Aeronautical Power Plant Research Engineer**—Duty post: Washington, D.C. Work assignments include the development of general designs and studies of reciprocating, turbojet, turboprop, ram-jet, pulsejet, and rocket engines to be used in Naval aircraft and guided missiles; project engineering in connection with turbojet power plants for piloted aircraft. This position is open at several levels with varying degrees of final responsibility: GS-5, $3,410 per annum; GS-7, $4,205 per annum; GS-9, $5,060 per annum; GS-11, $5,940 per annum; and GS-12, $7,040 per annum. **Mechanical or Aeronautical Engineer**—GS-11, $5,940 per annum. Duty post: Washington, D.C. Responsible for administering research contracts and projects for the development of transparent areas of cockpit and cabin enclosures of Naval aircraft, including windshield-wiper installations, degreasing systems, and washing systems. Basic requirements for all the above positions include Bachelor's Degree from an accredited institution and, in addition, professional engineering experience as follows: for GS-12, 3½ years; GS-11, 2½ years; GS-9, 1½ years; GS-7, ½ year. Interested personnel can obtain Application for Federal Employment (Form 57) from any U.S. Post Office; completed form or other communication should be addressed: Mr. E. N. Wolfe, Room 3909, Main Navy Building, 19th and Constitution Ave., N.W., Washington 25, D.C.

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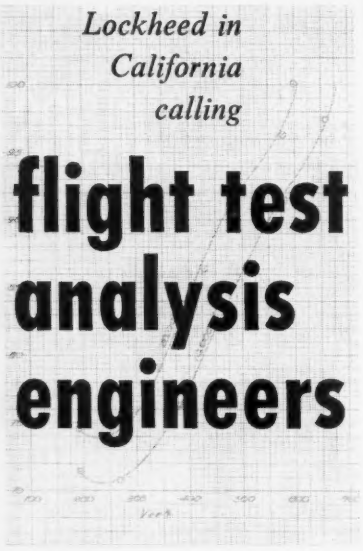

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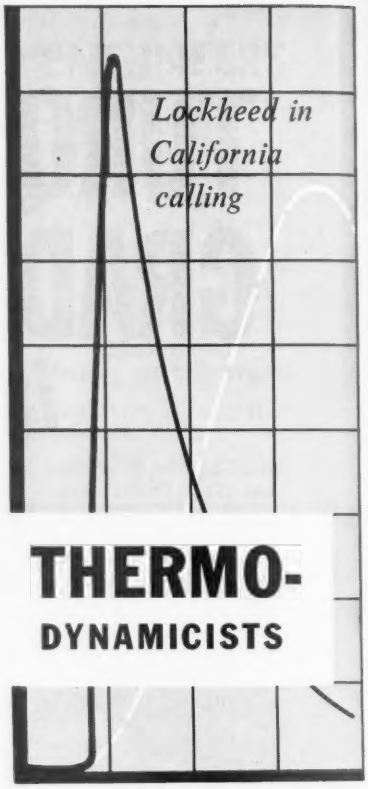

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Steel Wire Electroplated with Copper. Descriptive bulletin No. 201 on "Copperply." **National-Standard Co., Niles, Mich.**

"1954 Aluminum Mill Products Design." Twelve-page descriptive brochure. **Reynolds Metals Co., Desk PR, 2500 S. Third St., Louisville 1, Ky.**

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"Nickel Chrome Castings to Resist Heat & Corrosion." Four-page engineering data bulletin No. 1. **Standard Alloy Co., Inc., 1679 Collamer Rd., Cleveland 10, Ohio**

Analysis of Gold & Gold Alloy Solutions. Six-page article. **Technic, Inc., 39 Snow St., Providence 1, R.I.**

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Aircraft Accessories Catalog. Forty-four pages describe landing gear parts, brake systems components, propellers, instruments, fuel and oil systems equipment, emergency equipment, etc. **Air Associates, Inc., Dept. A, Teterboro, N.J.**

Butterfly-Type Air Valves. Specifically designed for low-leakage, high-temperature, and high-pressure aircraft applications. Bulletin F-6021. **Barber-Colman Co., Aircraft Controls Div., Rockford, Ill.**

T-Nut Isolator. For isolation of noise and vibration in grommet-type applications. **The Barry Corp., 871 Pleasant St., Watertown 72, Mass.**

Valves for Aircraft & Guided Missiles. Forty-eight-page descriptive catalog No. 200. **Bridgeport Thermostat Div., Robertshaw-Fulton Controls Co., Dept. A, Bridgeport, Conn.**

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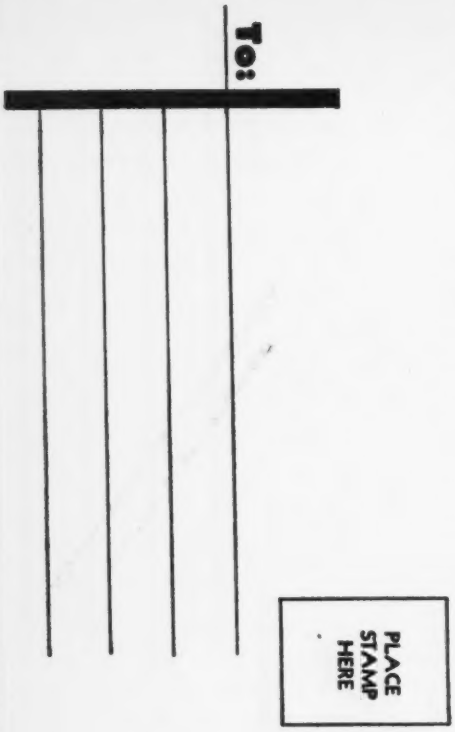

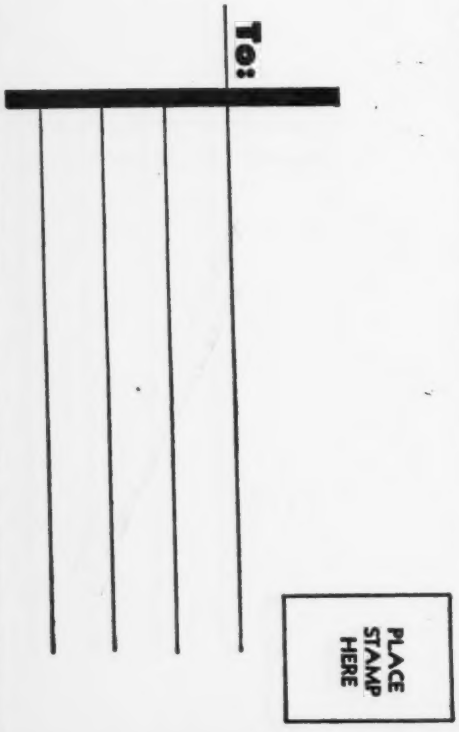

Thermocouple Protection Tube. Four-page descriptive bulletin No. P1261. **The Bristol Co., Waterbury 20, Conn.**

Chrome-Alloy Steel and Stainless-Steel Balls. For ball bearings, instruments, and jet engines. Four-page descriptive catalog. **Coolidge Corp., Middletown, Ohio**

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"O-Ring Engineering Handbook No. 504." Contains complete engineering data on O-ring seals. **Plastic & Rubber Products Co., 2100 Hyde Park Blvd., Los Angeles 47, Calif.**

"Inside Revere. . ." Twenty-four-page facilities booklet. **Revere Corp. of America, Inc., Wallingford, Conn.**

Tapping Screws. Descriptive 8-page booklet No. TL-88. **Townsend Co., New Brighton, Pa.**

Hydraulic Fluid Booster Pump. For use where hydraulic reservoirs are located at an extended distance from the system hydraulic pumps or where altitude problems exist. Brochure No. 5228. **Vickers Inc., 1400 Oakman Blvd., Detroit 32, Mich.**

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Wire-Wound Trimming Potentiometer. Descriptive 6-page brochure No. 3591. **Bourns Laboratories, Dept. NL, 6135 Magnolia Ave., Riverside, Calif.**

AN-"E" Series of Multicontact Electric Connectors. Descriptive 8-page bulletin No. AN-E-1. **Cannon Electric Co., P.O. Box 75, Lincoln Heights Station, Los Angeles 31, Calif.**

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RVP 7/8-In. Miniature Potentiometer. For applications where electrical and mechanical accuracies of precision potentiometers are required. **Technology Instrument Corp., 531 Main St., Acton, Mass.**

Type MXT-1 Snap-Action Switch. Featuring a direct-acting hinged leaf actuator, this unit is suitable for use in cam.- or slide-operated controls. **Unimax Switch Div., The W. L. Maxon Corp., 460 W. 34th St., New York 1, N.Y.**

Miniature Rectangular Connectors. VT series available with 7, 8, 14, 18, 20, 21, 34, and 41 contacts. **Viking Electric, 1061 Ingraham St., Los Angeles 17, Calif.**

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Dry Chemical Fire Extinguishers. Four-page descriptive folder. **American-LaFrance-Foamite Corp., Elmira, N.Y.**

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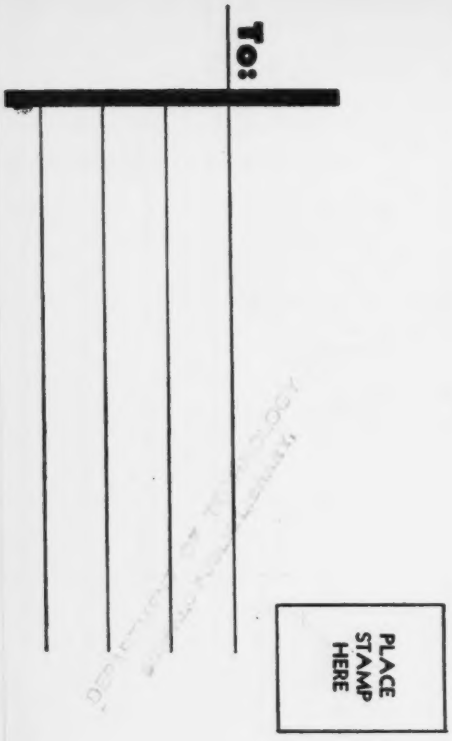

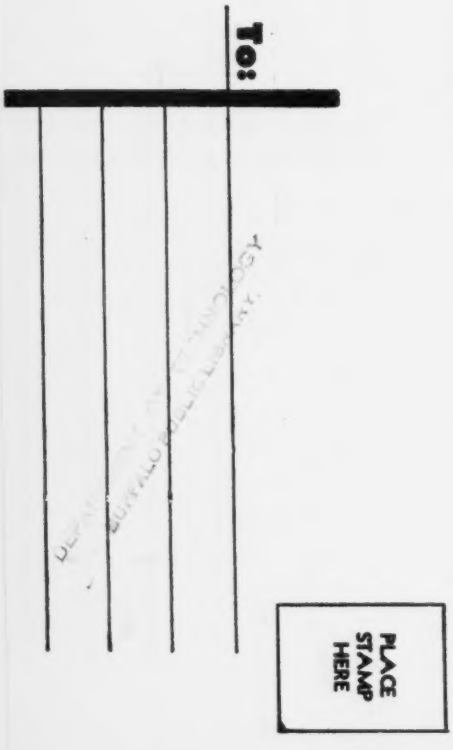

Small Laboratory & Production Rolling Mills. Eight-page descriptive booklet No. 121. **Stanat Mfg. Co., Long Island City, N.Y.**

"Allcase" High Production Batch Furnace. Six-page illustrated bulletin No. SC-163. **Surface Combustion Corp., Advertising Dept., Toledo 1, Ohio**

Three-Dimensional Hydraulic Tracer. This unit permits duplication of any unusually contoured aircraft part by tracing 360° in all directions. Bulletin A-6. **True-Trace Sales Corp., 2303 Chico Ave., El Monte, Calif.**

"Koldwelding Tool." For lap welding of aluminum sheet or foil without heat or electricity, and without flux or chemical. **Utica Drop Forge & Tool Corp., 2415 Whitesboro St., Utica 4, N.Y.**

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'Boscar" Data Reduction Machine. This unit permits rapid and accurate analysis of aerial gunnery photographs, boresight films, high-speed photographs of take-off and landing test runs, etc. **Benson-Lehner Corp., 2340 BQ Sawtelle Blvd., W. Los Angeles 64, Calif.**

Ultrasonic Thickness Measuring Instruments. Four-page folder giving specifications and applications. **Branson Instruments, Inc., 430 Fairfield Ave., Stamford, Conn.**

Precision Test Instruments. Sixteen-page catalog No. 106, describes dial indicators, test sets, depth gages, lens measures, and accessories. **Dial Indicator Co., 180 Wacker Dr., Chicago 6, Ill.**

Cyclograph Testing Equipment for Sorting Metals. Sorts raw stock, semi-finished, or finished metal parts by their metallurgical characteristics. **J. W. Dice Co., 1 Engle St., Englewood, N.J.**

Nondestructive Physical Testing and Measuring Instruments. Descriptive bulletin No. 32. **J. W. Dice Co., 1 Engle St., Englewood, N.J.**

Resistance Temperature Detector. Model 166KC, designed primarily for service on sleeve bearing motors as an over-temperature detector. **Thomas A. Edison, Inc., Instrument Div., West Orange, N.J.**

Unit for Demonstrating Fluid Mechanics. An adjustable-blade, multistage, axial-flow fan with a cradled d.c. dynamometer. **General Electric Co., Schenectady 5, N.Y.**

Ballistic Pendulum. Model AT-2 for the generation of single shock pulses of known acceleration. **Gulton Mfg. Corp., Metuchen, N.J.**

Blast Gage. Model P-401 designed for evaluation of magnitude and wave shape of sharp transient air blasts produced by explosives or other means. **Gulton Mfg. Corp., Metuchen, N.J.**

Decade Amplifier. Model F-408, a self-contained a.c. operated instrument designed for general laboratory use. **Gulton Mfg. Corp., Metuchen, N.J.**

"Peravia" Recording Instruments. These Swiss-made units include tachometers, tachographs, motographs, altimeters, barographs, accelerometers, etc. **The Matisa Equipment Corp., Instrument Div., 224 S. Michigan Blvd., Chicago 4, Ill.**

Hand Tachometer. A novel thumb-operated range selector automatically changes the scale numbers for each range. **Metron Instrument Co., 432 Lincoln St., Denver 3, Colo.**

Helium Attachment for X-Ray Spectrograph. Permits use of helium instead of air in the path of the X-ray beam, thus extending the useful spectrum range. **North American Philips Co., Inc., Research & Control Instruments Div., 750 S. Fulton Ave., Mount Vernon, N.Y.**

"Research & Control Instruments—X-Ray and Analytical Equipment." Sixty-four page reference book. **North American Philips Co., Inc., Research & Control Instruments Div., 750 S. Fulton Ave, Mt. Vernon, N.Y.**

Gear Analyzer. Permits visual observation of a magnified gear under simulated operating conditions. **Optical Gaging Products, Inc., 26 Forbes St., Rochester 11, N.Y.**

Optical Pyrometer. Descriptive 8-page catalog No. 85. **The Pyrometer Instrument Co., Inc., Bergenfield, N.J.**

Mercury Rectifier Power Drive. Converts alternating current to controlled d.c. variable voltage for application to adjustable speed drive equipment. **Reliance Electric & Engineering Co., 1088 Ivanhoe Rd., Cleveland 10, Ohio**

Multiple Cable & Wire Tester. For prestretching and proof-testing aircraft cable and other wire assemblies. Bulletin RE-9-53. **Riehle Testing Machines Div., American Machine & Metals, Inc., East Moline, Ill.**

Electronic Controllers. For automatic production, quality control testing, and research programs. **Tinius Olsen Testing Machine Co., 1004 Easton Rd., Willow Grove, Pa.**

Test Instruments. Aircraft temperature measuring system components and aircraft instrument testing devices. **The Winslow Co., 9 Liberty St., Newark, N.J.**